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# **APOLLO OPERATIONS HANDBOOK**

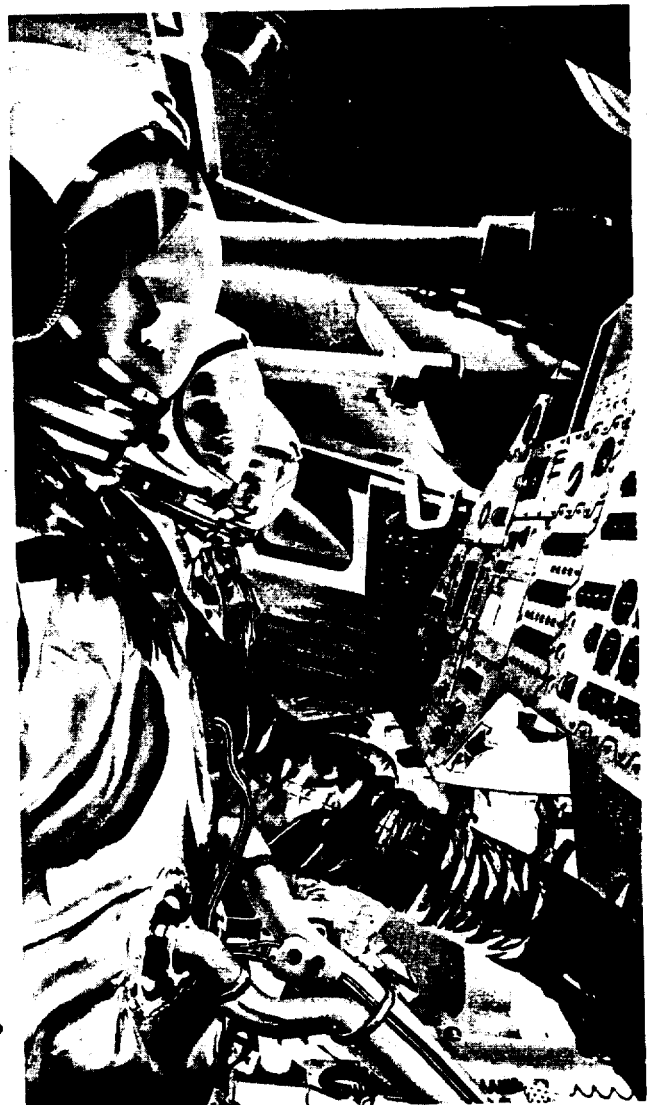
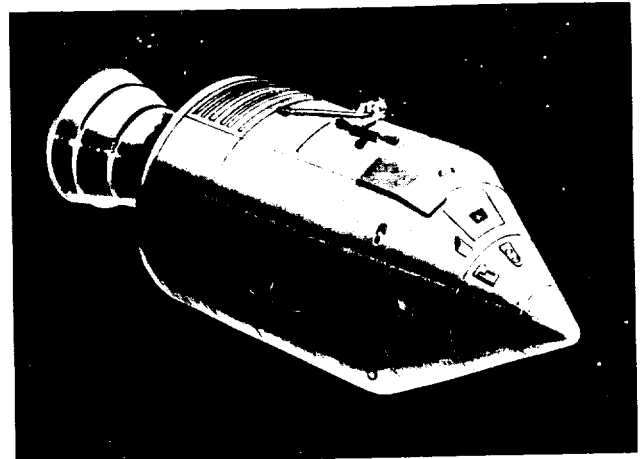
**COMMAND AND  
SERVICE MODULE**

**SPACECRAFT 012**

Prepared Under Direction of  
**NASA-MSC MISSION OPERATIONS BRANCH  
FLIGHT CREW SUPPORT DIVISION**



**NORTH AMERICAN AVIATION, INC.  
SPACE and INFORMATION SYSTEMS DIVISION**







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APOLLO OPERATIONS HANDBOOK  
COMMAND AND SERVICE MODULE  
SPACECRAFT 012

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## APOLLO OPERATIONS HANDBOOK

**LIST OF EFFECTIVE PAGES**

NOTE: The portion of the text affected by the current changes is indicated by a vertical line in the outer margins of the page.

TOTAL NUMBER OF PAGES IN THIS PUBLICATION IS 816,  
CONSISTING OF THE FOLLOWING:

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## CHANGE INFORMATION

This handbook is subject to continuous change or revision, on a priority basis, to reflect current engineering or mission changes, or to improve content or arrangement. The content and the changes are accounted for by the above List of Effective Pages, and by the following means:

Record of Publication: The publication date of each basic issue and each change issue is listed on page B as a record of all editions.

Page Change Date: Each page in this handbook has space for entering a change date. The latest publication date will be entered in this space each time a page is changed from the basic issue.

\*The asterisk indicates pages changed, added, or deleted by the current change.

Manuals will be distributed as directed by the NASA Apollo Program Office. All requests for manuals should be directed to the NASA Apollo Spacecraft Program Office at Houston, Texas.

### RECORD OF PUBLICATION

This issue of the Apollo Operations Handbook, Spacecraft 012, dated 12 November 1966, constitutes a revision of the handbook, dated 16 September 1966. Subsequent changes may be issued to maintain information current with spacecraft configuration through completion of the mission. This record will reflect the publication date of any released changes.



LATE TECHNICAL CHANGES

The items listed below represent technical changes which have been approved too late for inclusion in the 12 November 1966 printing of the Apollo Operations Handbook.

Source	Description of Change	Section Affected
MCR A1735	Change S/M RCS fuel from blended hydrazine mixture to monomethylhydrazine	2.5
MCR 1591 REV 3.	Addition of inverter synchronizer power panel which provides circuit breakers for the control of power to the phase synchronizer unit.	2,3
FEO M-53025 (10-13-66)	This is a nomenclature correction for the S-Band switch on the MDC panels No. 13, 23 and 26. This change is required due to wiring changes. The S-Band switch was marked "PTT", "OFF" and "VOX". The switch is now marked "OFF", "OFF" and "T/R".	2.8 and 3
MCR A1733 (10-11-66)	Modification of Crew Couch Lockouts. This MCR removes the lockout solenoid actuator and wire harness from the X-X axis strut lockout mechanism. Add an adapter to the lockout mechanism assembly to fix in the locked position. The switch on panel No. 9 and the wire harness assembly on the struts will be removed.	1,2,3

### SYNOPSIS OF SIGNIFICANT CHANGES

This tabulation does not list all changes, additions, and/or deletions in the handbook. Its purpose is to assist the reader in determining the significant technical changes in each system.

#### PART I. TECHNICAL CHANGES

Handbook Section(s) Affected	Description	Handbook System(s) Affected
1	Updated lockout mechanisms on shock struts.	GEN
1	Updated forward hatch cover.	GEN
2	Revised RCSC circuit diagram to include entry battery backup power to pyro bus.	SEQ
2	H <sub>2</sub> purge line heater	EPS
2	Fuel cell H <sub>2</sub> and O <sub>2</sub> reactant shutoff valves holding voltage control	EPS
2	Cryogenic system response and operation	EPS
2	Revised, updated, and assembled end-to-end circuit and system diagrams. Added electrical power distribution diagrams and power requirements. Added operating ranges and panel references to measurement lists.	PROP
4	Added tabular data for color markings contained on indicator displays and updated art.	SPS, EPS and ECS
4	Added typical charts from MMDB to determine S/C consumable data.	RCS, SPS and EPS
4	Added data on S/C attitude controls.	RCS
4	Updated SPS Delta V and Engine Gimbal Angle charts.	SPS

### FOREWORD

This handbook and its contents are restricted to the requirements for Spacecraft 012. It presents, in one document, descriptions of the spacecraft systems and equipment, and listings of the flight crew operational procedures necessary for the safe and efficient function of the spacecraft throughout its planned mission. This handbook is designed primarily for use by the flight crew, and secondarily for use by the mission flight controllers, flight planners, and trainer operators.

NASA comments or suggested changes to this handbook should be addressed to the Flight Planning Section, FCSD, MSC, Office Code CF 32, Telephone HU3-4271.





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SECTION 1

GENERAL INFORMATION

INTRODUCTION.

This section contains information relating to the Apollo spacecraft 012 configuration, and a description of the launch vehicle and booster used for the mission.

1.1 SPACECRAFT 012 CONFIGURATION.

Spacecraft 012 (figure 1-1) conforms to a Block I CSM configuration consisting of a launch escape system (LES) assembly, command module (C/M), service module (S/M), and the spacecraft lunar excursion module adapter (SLA). This spacecraft, designed for an earth orbital mission, does not contain a lunar module (LM) within its adapter. (For a description of the launch vehicle used with spacecraft 012, refer to paragraph 1.2)

**NOTE** The Block I configuration missions for the Apollo program provide the following:

- Command module and service module development for earth orbital missions
- Demonstration of systems operational capabilities including all types of aborts, land and water recovery, Saturn IB and Saturn V operation and capability, and systems operation during earth orbit
- Development of qualified teams for checkout, launch, manned space flight network (MSFN), recovery, and flight analysis.

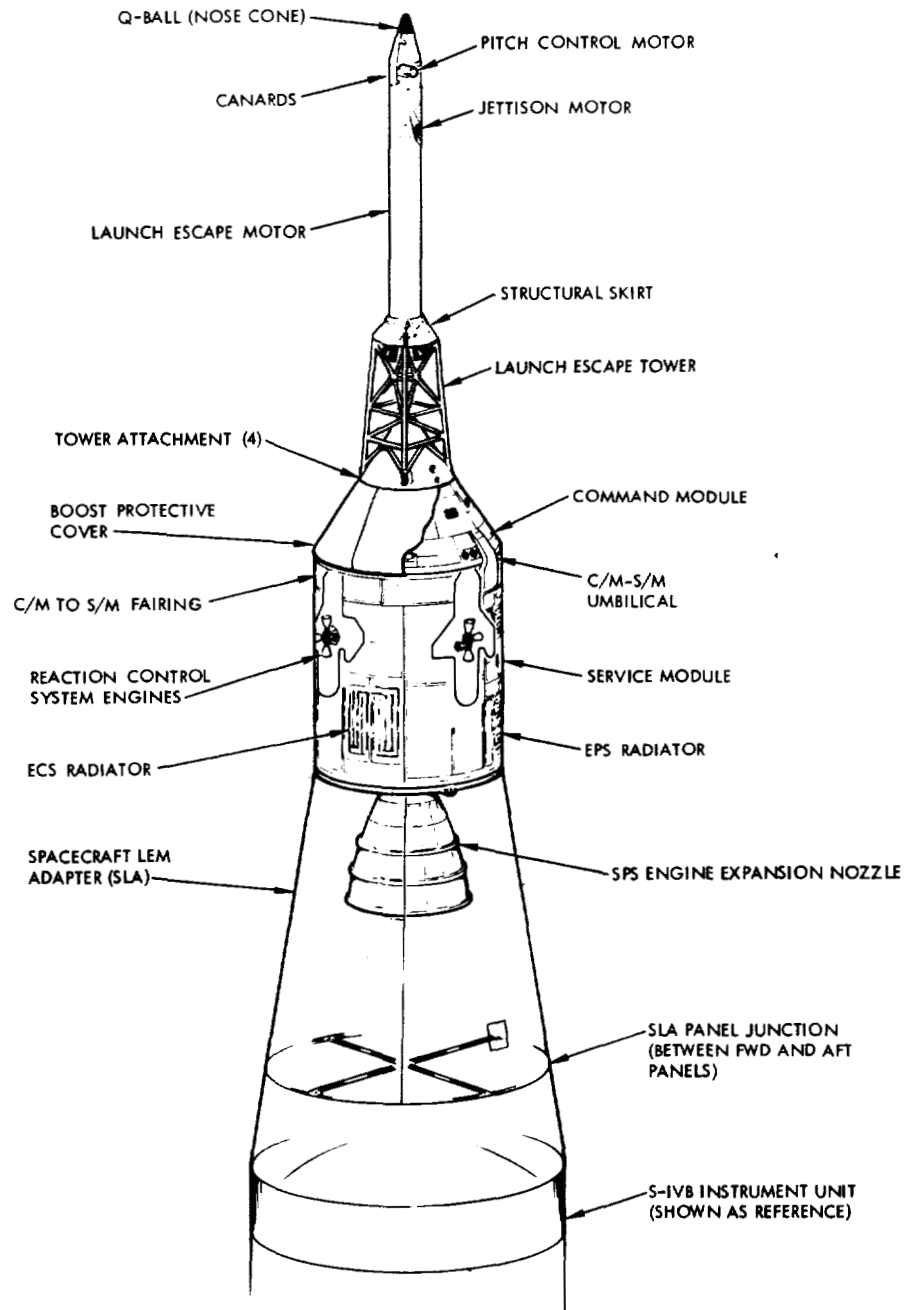
1.1.1 LES ASSEMBLY.

The LES assembly (figure 1-1) provides the means for separating the C/M from the launch vehicle during pad or suborbital aborts. This assembly consists of a Q-ball instrumentation assembly (nose cone), ballast compartment, canard surfaces, pitch control motor, tower jettison motor, launch escape motor, a structural skirt, an open-frame tower, and a boost protective cover (BPC). The structural skirt at the base of the housing, which encloses the rocket motors, is secured to the upper portion of the tower.

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Figure 1-1. Spacecraft 012 Configuration (Sheet 1 of 2)

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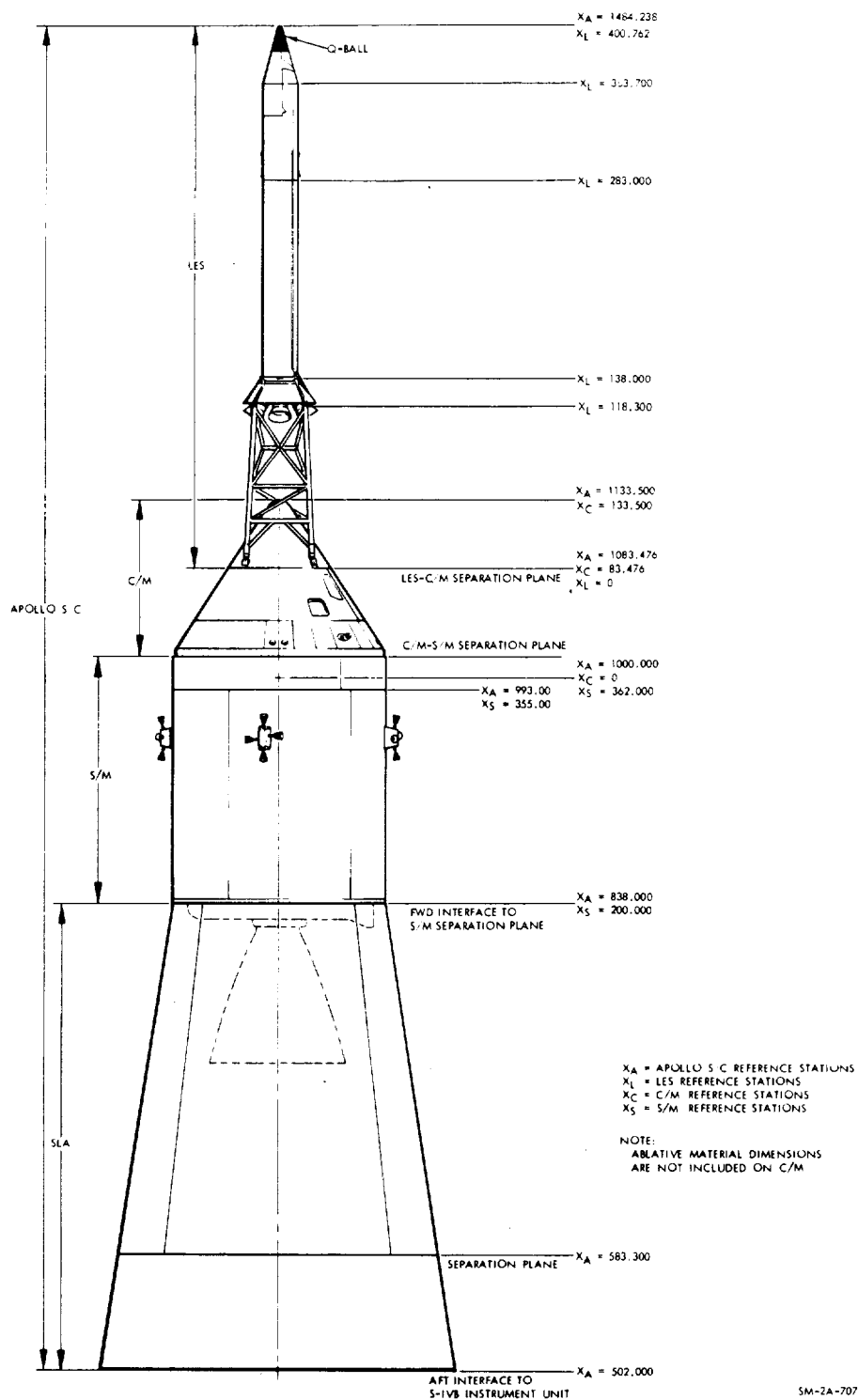


Figure 1-1. Spacecraft 012 Configuration (Sheet 2 of 2)

SPACECRAFT 012 CONFIGURATION

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The BPC (figure 1-2) is attached to the lower end of the tower to protect the C/M from thermal heat during boost and from exhaust damage by the launch escape and tower jettison motors. Explosive nuts, one in each tower well leg, secure the tower to the C/M structure. (For additional information, refer to the sequential systems in section 2.)

1.1.2 COMMAND MODULE.

The C/M (figure 1-3) forms the spacecraft control center, contains necessary automatic and manual equipment to control and monitor the spacecraft systems, and contains the required equipment for safety and conform of the crew. The module is an irregular-shaped, primary structure encompassed by three heat shields (coated with ablative material and joined or fastened to the primary structure) forming a conical-exterior shape. The C/M consists of a forward compartment, a crew compartment, and an aft compartment.

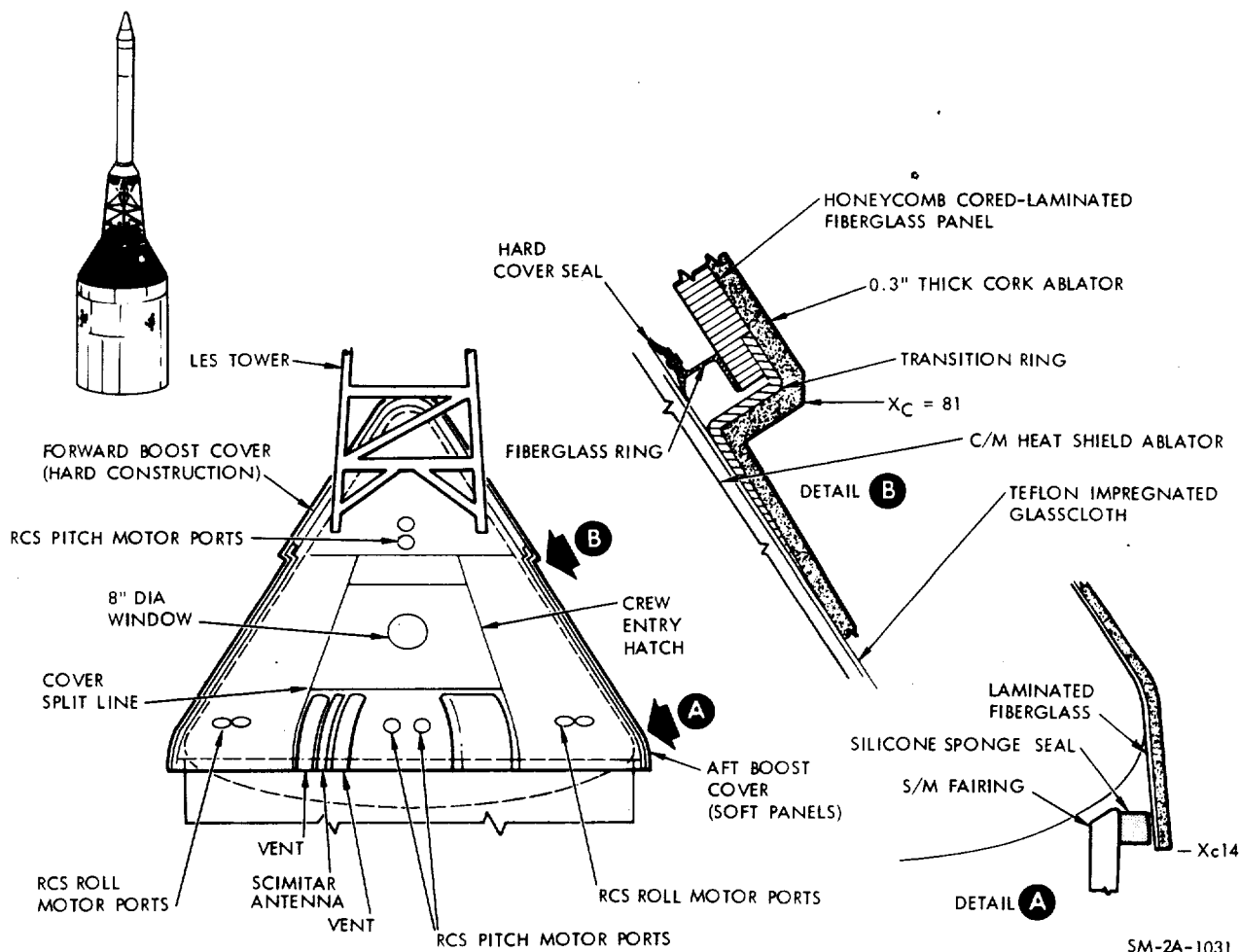
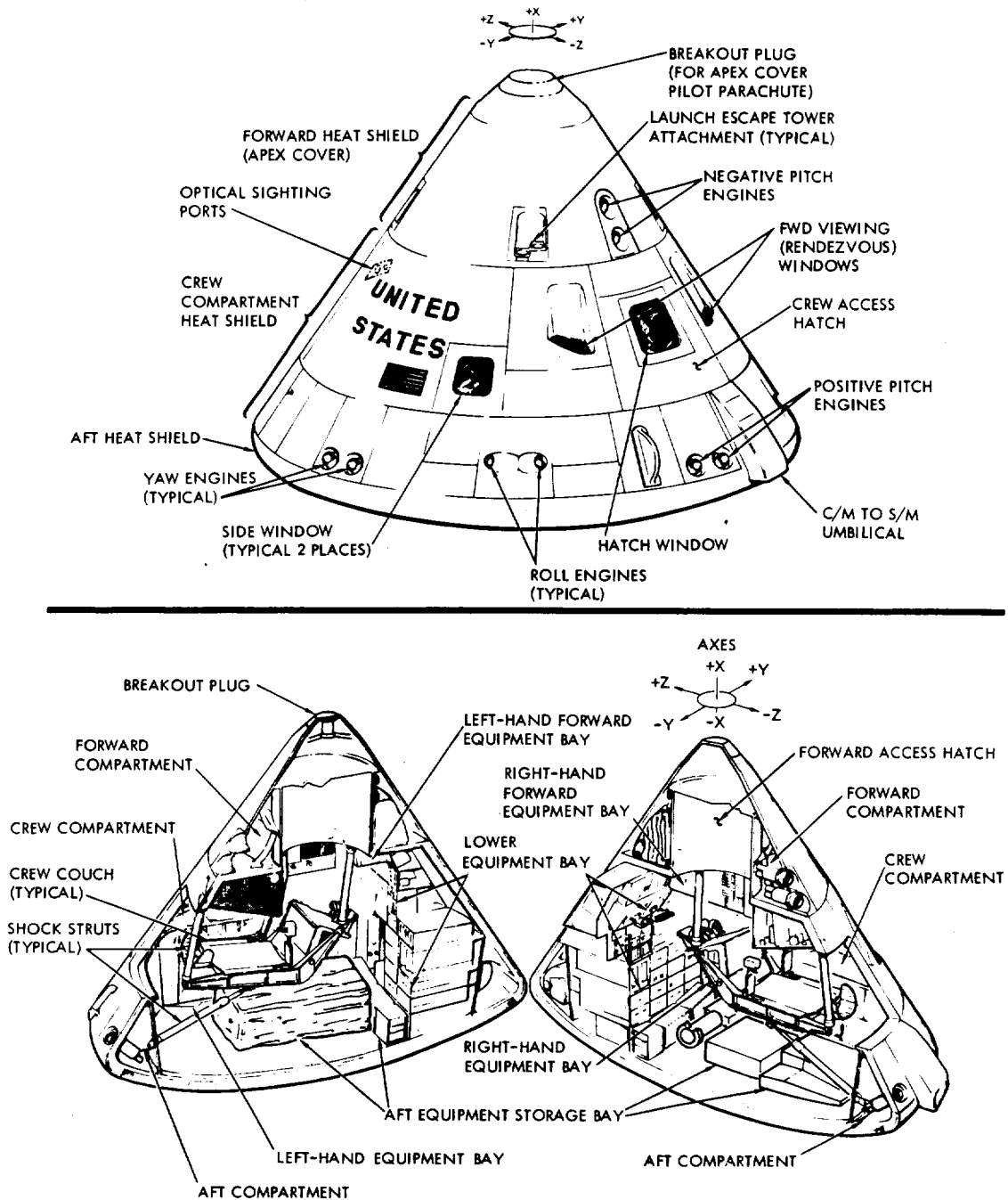


Figure 1-2. Boost Protective Cover

SPACECRAFT 012 CONFIGURATION

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NOTE:  
CENTER COUCH REMOVED FOR CLARITY.

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Figure 1-3. Spacecraft 012 Command Module

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1.1.2.1 Forward Compartment.

The forward compartment (figure 1-3) is the area outside the forward access tunnel, forward of the crew compartment forward bulkhead and is covered by the forward heat shield. Four 90-degree segments around the perimeter of the tunnel contain the recovery equipment, two negative-pitch reaction control system engines, and the forward heat shield release mechanism. Most of the equipment in the forward compartment consists of earth landing (recovery) system components.

The forward heat shield, or apex cover, is made of brazed stainless-steel honeycomb and covered with ablative material. It contains four recessed fittings which permit the launch escape tower to be attached to the C/M inner structure. Jettison thrusters separate the apex cover from the C/M after entry or after the launch escape assembly is separated during an abort. (For additional information, refer to the sequential systems in section 2.)

1.1.2.2 Crew Compartment.

The crew compartment or inner structure (figure 1-3) is a sealed cabin with pressurization maintained by the environmental control system (ECS). The compartment, protected by a heat shield, contains controls and displays for operation of the spacecraft and spacecraft systems; contains mechanical adjustments for the crew couches, restraint harness assemblies, hatch covers, window shades, etc.; and is provided with crew equipment, food and water, waste management provisions, survival equipment, and scientific experiments equipment. Access hatches, observation windows, and equipment bays are attached as part of the compartment structure.

The crew compartment heat shield, like the apex cover, is made of brazed stainless-steel honeycomb and covered with ablative material. This heat shield, or outer structure, contains the S/C umbilical connector outlet, ablative plugs, and a copper heat sink for the optical sighting ports in the lower equipment bay, two side observation windows, two forward viewing windows, and the outer cover for the side access hatch which also contains an observation window.

1.1.2.3 S/C Controls and Displays.

Information relating to controls and displays for operation of the spacecraft and its systems is provided in section 3.

1.1.2.4 C/M Mechanical Controls.

Mechanical controls (figure 1-4) are provided in the crew compartment for manual operation of the crew couch assembly, side access hatch covers, forward access hatch cover, and manual override levers for the

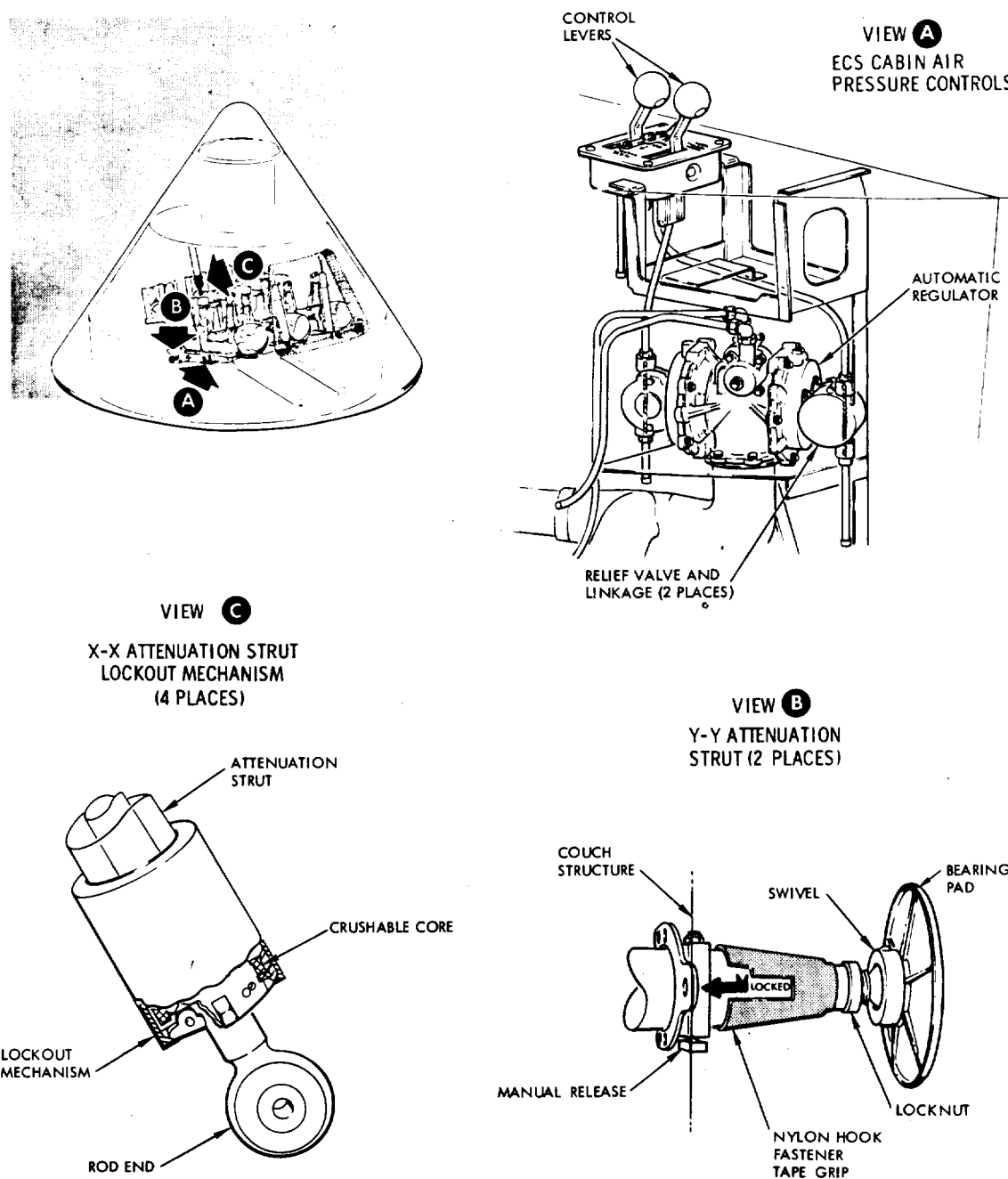
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Figure 1-4. C/M Mechanical Controls (Sheet 1 of 3)

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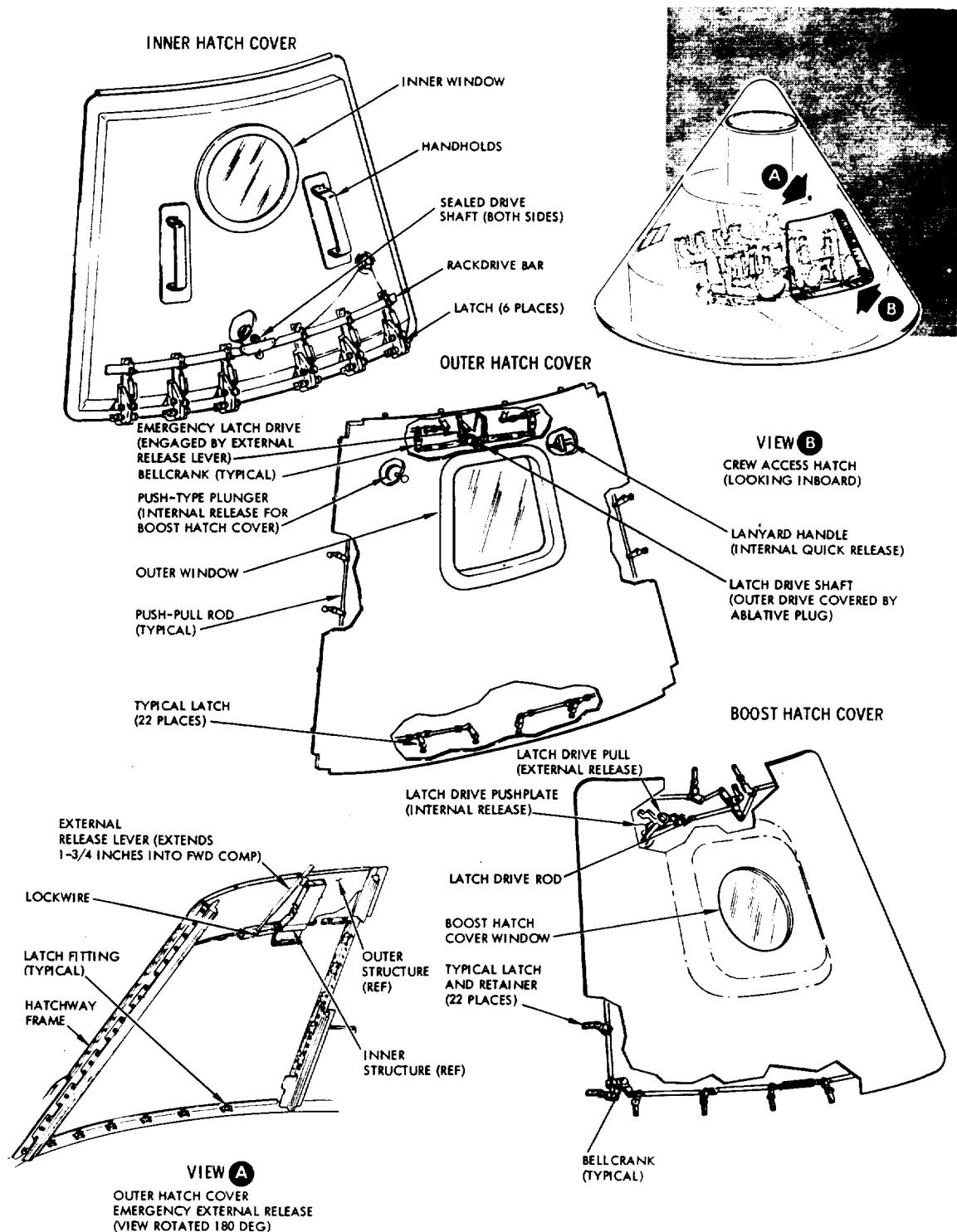


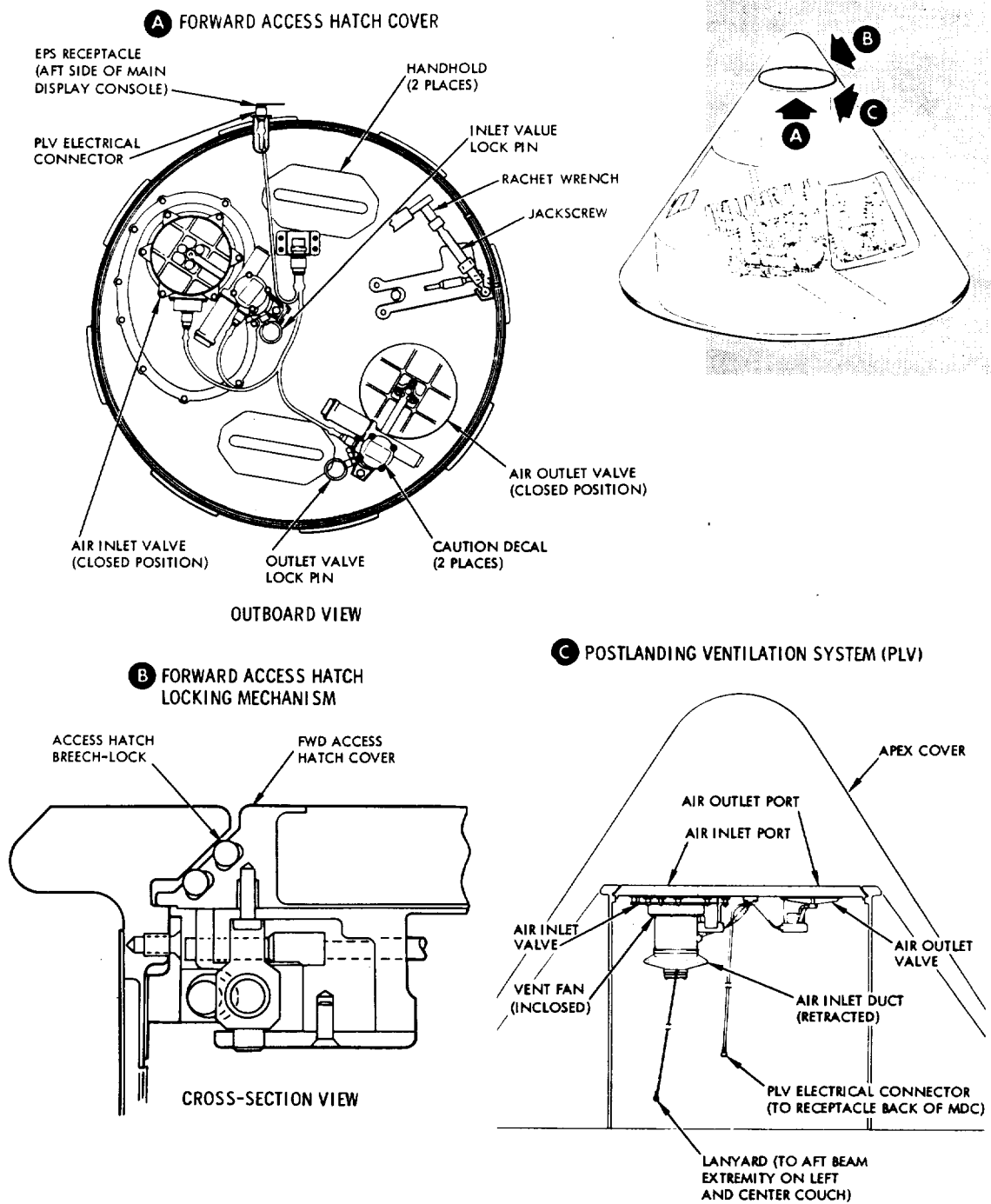
Figure 1-4. C/M Mechanical Controls (Sheet 2 of 3)

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Figure 1-4. C/M Mechanical Controls (Sheet 3 of 3)

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socket at one end) is mounted on the cover and will bear against a bracket on the tunnel wall. When turned by a handcrank or torque wrench with a 5/32-inch drive, the jackscrew will intend and allow the cover to be rotated and removed. The cover is rotated by use of the inside handholds or the outside by an item of GSE and can only be retrieved from within the crew compartment end of the tunnel.

## 1.1.2.4.5 Windows and Shades.

Five windows are provided through the inner structure and heat shield of the C/M: two forward viewing, two side observation, and the crew access hatch windows. (See figure 1-3.) During orbital flight, photographs of external objects will be taken through the viewing and observation windows. The inner windows (including the circular inner hatch window) are made of tempered silica glass with 0.25-inch-thick double panes, separated by 0.1 inch of space, and have a softening temperature point of 2000°F. The outer windows (including the square outer hatch window) are made of amorphous fused silicon with a single 0.7-inch-thick pane. Each pane contains an antireflecting coating on the external surface, and has blue-red reflective coating on the inner surface for filtering out most infrared and all ultraviolet rays, a softening temperature point of 2800°F, and a melting point of 3110°F.

Shades are provided for controlling external light entering the C/M through the triangular forward viewing windows, the square side observation windows, and the circular inner hatch window. These shades, individually designed for each window configuration, are made of mylar film which has been heat-treated to roll up when not held flat. The shades are opaque for zero light transmittal, have a nonreflective inner aluminized surface, two snap fasteners and fabric handles for attaching or removing from a particular window, and a 3/4-inch strip of Velcro hook material around the outer surface for holding the shade against the Velcro pile around the perimeter of the window. If desired, a shade can be peeled back from the Velcro pile material and stowed in place on one side of the window.

## 1.1.2.4.6 Cabin Pressure Controls.

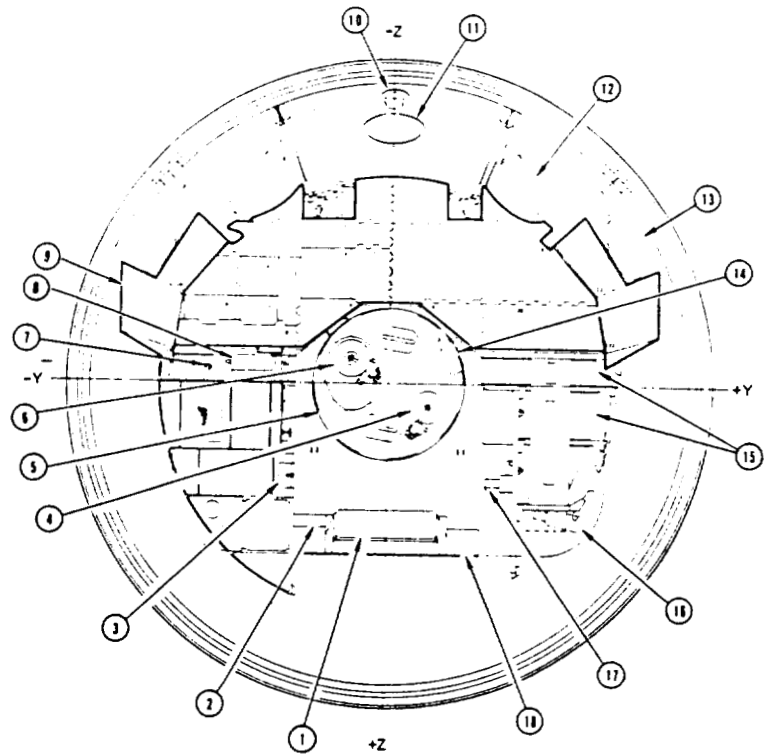
Two control levers for manually operating the ECS cabin pressure relief valves are located near the C/M left couch and left side window. (See figure 1-4.) These levers are provided as a mechanical override for opening and closing the redundant sides of the automatic cabin pressure regulator. (For additional information, refer to the environmental control system in section 2.)

1.1.2.5 Crew Equipment and Equipment Bays.

Each crewmember has personal and accessory equipment provided for his use in the crew compartment. Major items of personal equipment consist of a pressure garment assembly (PGA) with attaching hose and umbilical, a communications assembly, a constant-wear garment, bio-medical sensors, and radiation dosimeters. Major items of accessory equipment shared by the crew consist of an in-flight tool set and a medical kit. (For a detailed list of crew equipment, refer to section 6.) (Specific items contained in the C/M equipment and storage bays are listed in figure 1-6.)

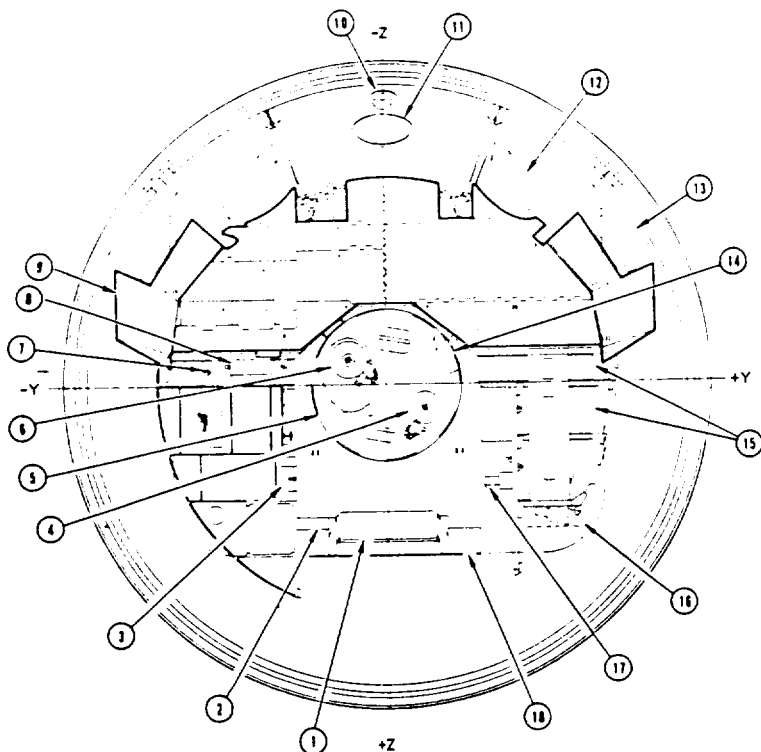
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## SPACECRAFT 012 CONFIGURATION



FORWARD REFERENCE VIEW	
<ul style="list-style-type: none"> <li>1 Optics shroud</li> <li>2 LEB lighting control panel</li> <li>3 Food reconstitution device</li> <li>4 Postlanding ECS air outlet duct</li> <li>5 Forward access hatch cover</li> <li>6 Postlanding ECS air inlet duct</li> <li>7 Water delivery valve</li> <li>8 Water delivery unit</li> <li>9 Main display console (MDC panels 1 through 26)</li> <li>10 Crew access hatch actuator (inner cover)</li> </ul>	<ul style="list-style-type: none"> <li>11 Crew access hatch inner window</li> <li>12 Forward viewing or rendezvous window (2 places)</li> <li>13 Side window (2 places)</li> <li>14 TV camera (launch and entry)</li> <li>15 Survival provisions</li> <li>16 TV camera mount (optional)</li> <li>17 Measurement system instrumentation</li> <li>18 Apollo guidance computer navigational display keyboard</li> </ul>

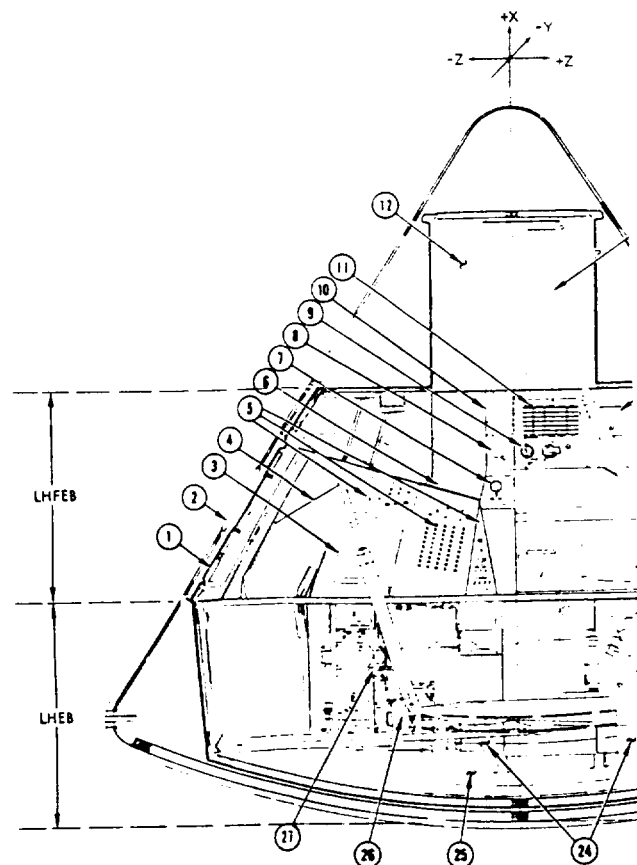




FORWARD REFERENCE VIEW

Optics shroud  
LEB lighting control panel  
Food reconstitution device  
Postlanding ECS air outlet duct  
Forward access hatch cover  
Postlanding ECS air inlet duct  
Water delivery valve  
Water delivery unit  
Main display console (MDC) panels  
1 through 26  
Crew access hatch actuator  
(inner cover)

11 Crew access hatch inner window  
12 Forward viewing or rendezvous  
window (2 places)  
13 Side window (2 places)  
14 TV camera (launch and entry)  
15 Survival provisions  
16 TV camera mount (optional)  
17 Measurement system instrumentation  
18 Apollo guidance computer navigational  
display keyboard



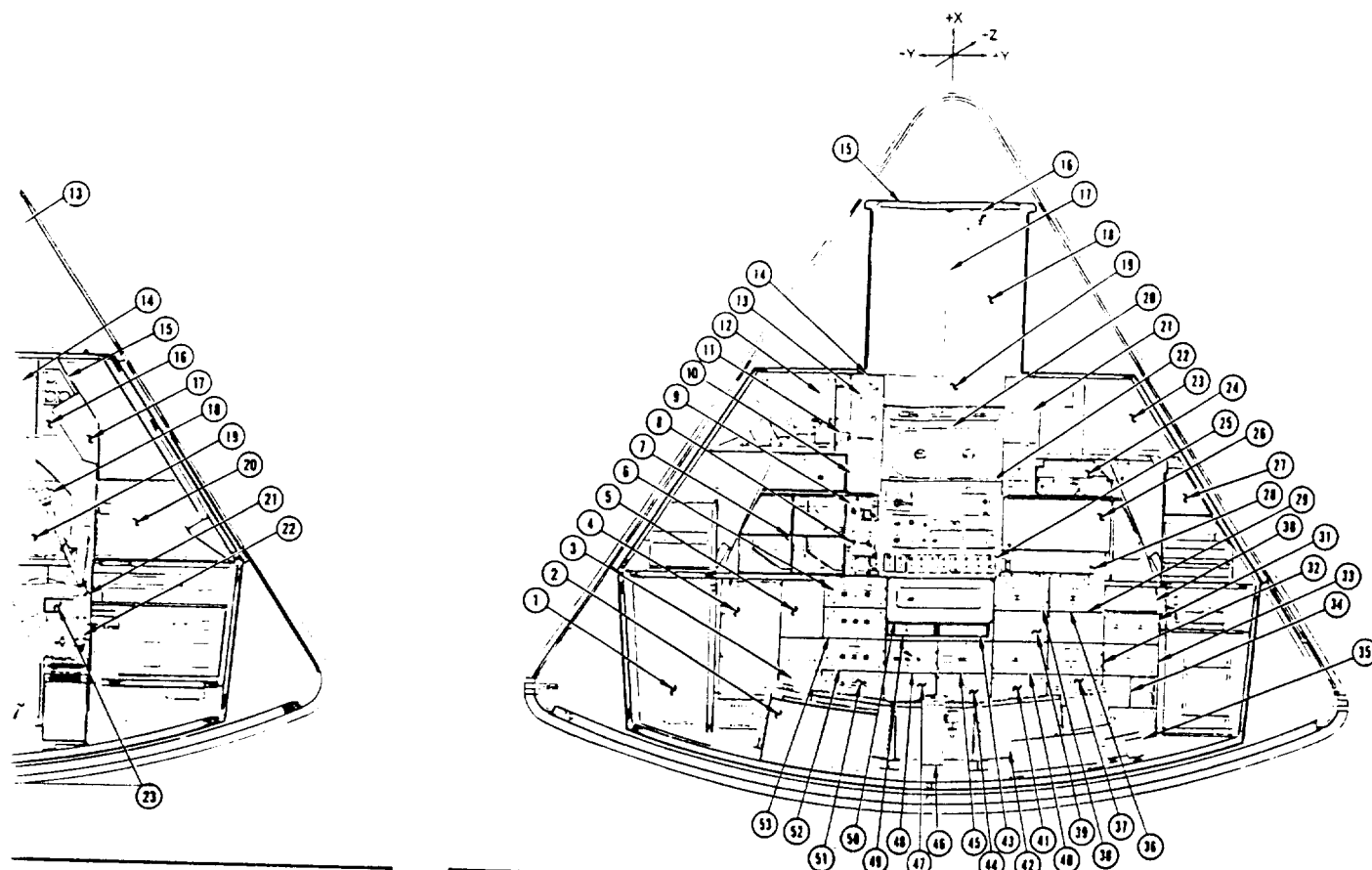
LEFT-HAND FORWARD EQUIPMENT BAY (LHFE) AND LEFT

1 Inner hatch cover  
2 Outer hatch cover  
3 Side window  
4 Rendezvous window housing  
5 Side console panels (left)  
6 Main display console (ref)  
7 Comdr suit connector panel and electrical connector  
8 Sr pilot suit connector panel and electrical connector  
9 Pilot suit connector panel electrical connector  
10 Scientific equipment compartment D  
11 Cabin air recirculation fan  
12 Forward access hatch or egress tunnel (ref)  
13 Postlanding ECS air inlet duct (extended)

15 Clock and  
16 G&N load  
17 Sextant a  
18 Crew att  
19 Clothing  
20 Inertial n  
21 Left crew  
22 Oxygen  
23 Medical  
24 Side sho  
25 Spacesuit  
26 ECS valv  
27 ECS oxyg







#### FORWARD ACCESS HATCH (FAH)

1. Event timer panel  
2. Spare parts storage  
3. Sextant and telescope compartment (ref)  
4. Attenuation strut (X-X axis)  
5. Storage compartment  
6. Measurement unit (ref)  
7. Couch (attenuated)  
8. Control panel  
9. Kit (left couch)  
10. Attenuation panels (removable)  
11. Storage bag and scientific equipment storage (ref)  
12. Oxygen, water, and glycol equipment

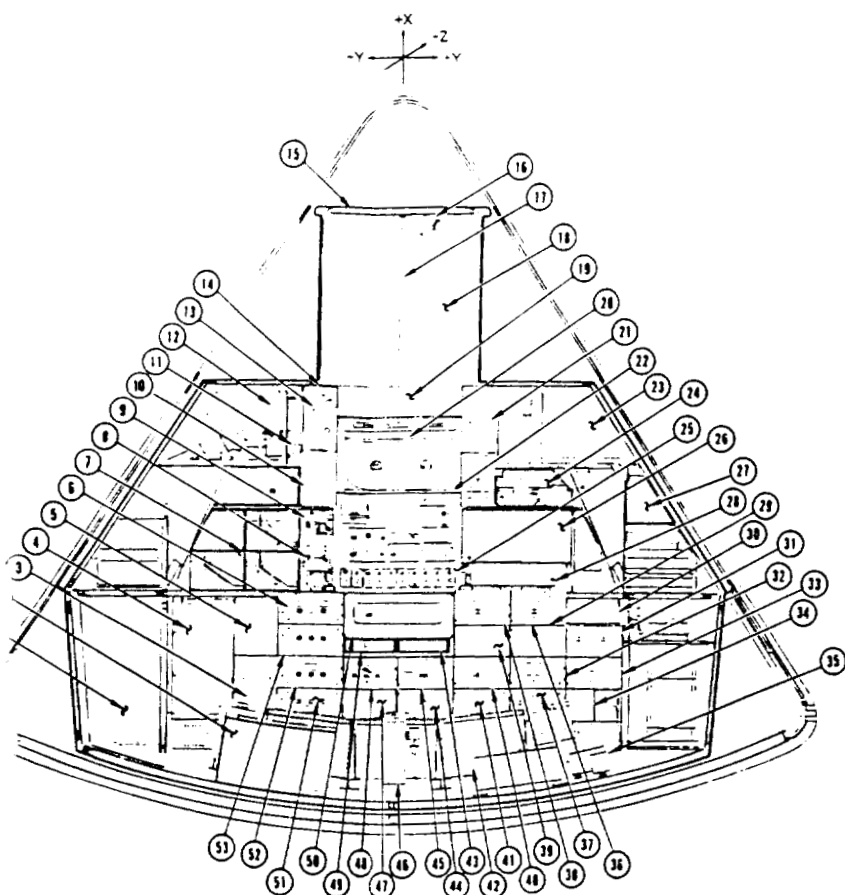
#### LOWER EQUIPMENT BAY (LEB)

- |   |   |
|---|---|
| 1 ECS components (ref)  | 28 Signal conditioning equipment                          |
| 2 Spacesuit storage bag and scientific equipment storage (ref)  | 29 VHF multiplexer  |
| 3 Gas chromatograph   | 30 Data wiring  |
| 4 Flight qualification tape recorder                            | 31 Premodulation processor                                |
| 5 Scientific equipment compartment A                            | 32 VHF recovery beacon and VHF-AM transmitter-receiver    |
| 6 Display/attitude gyro-accelerometer (ECA)                     | 33 Audio center   |
| 7 Food storage (5 containers)                                   | 34 Central timing   |
| 8 Attitude gyro and accelerometer                               | 35 TV optics storage (ref)                                |
| 9 Rate gyro   | 36 Pulse-code modulation (PCM) unit 2 telemetry equipment |
| 10 Coupling and display panel                                   | 37 VHF-FM transmitter and HF transceiver                  |
| 11 Sr pilot suit connector panel and electrical connector (ref) | 38 Pulse-code modulation (PCM) unit 1 telemetry equipment |
| 12 Cabin air recirculation fan (ref)                            | 39 Scientific equipment compartment C                     |
| 13 IMU control panel  | 40 S-band power amplifier                                 |
| 14 Lighting control   | 41 C-band transponder                                     |
| 15 Forward access hatch cover (ref)                             | 42 CO <sub>2</sub> absorber container (ref)               |
| 16 Postlanding ECS air outlet duct                              | 43 Food and work table (in-flight tool set)               |
| 17 Postlanding ECS power cable                                  | 44 Digital up-data link                                   |
| 18 Forward access hatch (ref)                                   | 45 Unified S-band equipment                               |
| 19 Sextant telescope eyepiece stowage                           | 46 Fecal canister (positioned)                            |
| 20 Sextant and telescope panel                                  | 47 Scientific equipment compartment B                     |
| 21 Computer display and control panel                           | 48 Roll channel ECA                                       |
| 22 G&N control panel IMU  | 49 Data package container (also on outboard couch beams)  |
| 23 Survival provisions (ref)                                    | 50 G&N computer   |
| 24 Clinical monitoring instrument set compartment               | 51 Pitch channel ECA                                      |
| 25 Power servo assembly (PSA)                                   | 52 Auxiliary ECA  |
| 26 Data storage equipment                                       | 53 Yaw channel ECA  |
| 27 Towel storage  |   |

#### RIGHT

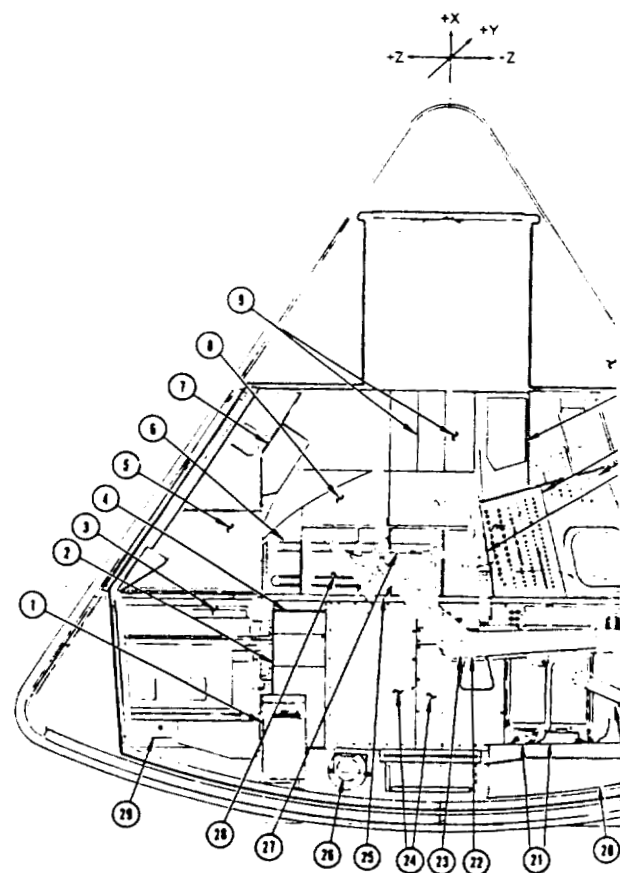
- |                            |
|----------------------------|
| 1 CO <sub>2</sub> absorber |
| 2 Waste man                |
| 3 Computer                 |
| 4 Vacuum ch                |
| 5 IMU comp                 |
| 6 Medical eq               |
| 7 Sextant and              |
| 8 Food stowag              |
| 9 Survival pa              |
| 10 RCS pitch e             |
| 11 TV camera               |
| 12 Side consol             |
| 13 Rendezvous              |
| 14 Inner hatch             |
| 15 Side window             |
| 16 Outer hatch             |





LOWER EQUIPMENT BAY (LEB)

<ul style="list-style-type: none"> <li>Components (ref)</li> <li>Storage bag and scientific equipment storage (ref)</li> <li>Photograph</li> <li>Calibration tape recorder</li> <li>Equipment compartment A</li> <li>Attitude gyro-accelerometer (ECA)</li> <li>Range (5 containers)</li> <li>Gyro and accelerometer</li> <li>and display panel</li> <li>Unit connector panel and electrical connector (ref)</li> <li>Recirculation fan (ref)</li> <li>Roll panel</li> <li>Control</li> <li>Access hatch cover (ref)</li> <li>ECS air outlet duct</li> <li>ECS power cable</li> <li>Access hatch (ref)</li> <li>Escape eyepiece storage</li> <li>Telescope panel</li> <li>Display and control panel</li> <li>Roll panel IMU</li> <li>Provisions (ref)</li> <li>Monitoring instrument set compartment</li> <li>Assembly (PSA)</li> <li>Te equipment</li> <li>ge</li> </ul>	<ul style="list-style-type: none"> <li>28 Signal conditioning equipment</li> <li>29 VHF multiplexer</li> <li>30 Data wiring</li> <li>31 Premodulation processor</li> <li>32 VHF recovery beacon and VHF-AM transmitter-receiver</li> <li>33 Audio center</li> <li>34 Central timing</li> <li>35 TV optics storage (ref)</li> <li>36 Pulse-code modulation (PCM) unit 2 telemetry equipment</li> <li>37 VHF-FM transmitter and HF transceiver</li> <li>38 Pulse-code modulation (PCM) unit 1 telemetry equipment</li> <li>39 Scientific equipment compartment C</li> <li>40 S-band power amplifier</li> <li>41 C-band transponder</li> <li>42 CO<sub>2</sub> absorber container (ref)</li> <li>43 Food and work table (in-flight tool set)</li> <li>44 Digital up-data link</li> <li>45 Unified S-band equipment</li> <li>46 Fecal canister (positioned)</li> <li>47 Scientific equipment compartment B</li> <li>48 Roll channel ECA</li> <li>49 Data package container (also on outboard couch beams)</li> <li>50 G&amp;N computer</li> <li>51 Pitch channel ECA</li> <li>52 Auxiliary ECA</li> <li>53 Yaw channel ECA</li> </ul>
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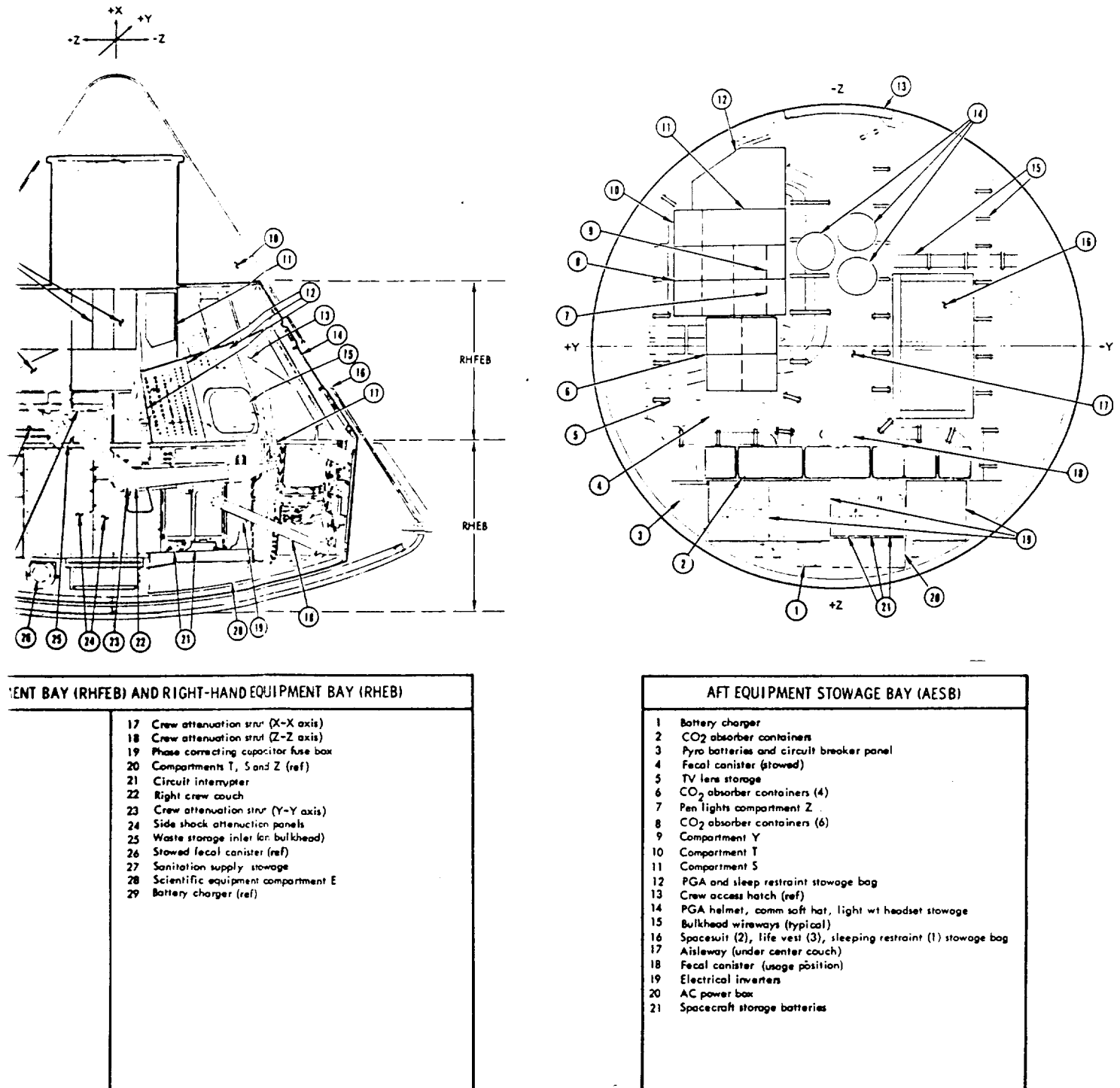


RIGHT-HAND FORWARD EQUIPMENT BAY (RHFE) AND RIGHT-HAND SIDE (RHS)

<ul style="list-style-type: none"> <li>1 CO<sub>2</sub> absorber container (ref)</li> <li>2 Waste management system</li> <li>3 Computer</li> <li>4 Vacuum cleaner compartment</li> <li>5 IMU compartment (ref)</li> <li>6 Medical accessories kit</li> <li>7 Sextant and telescope compartment (ref)</li> <li>8 Food storage</li> <li>9 Survival provisions</li> <li>10 RCS pitch control engine area (ref)</li> <li>11 TV camera mount</li> <li>12 Side console panels (right)</li> <li>13 Rendezvous window housing</li> <li>14 Inner hatch cover</li> <li>15 Side window</li> <li>16 Outer hatch cover</li> </ul>	<ul style="list-style-type: none"> <li>17 Crew attenuation str</li> <li>18 Crew attenuation str</li> <li>19 Phase correcting cap</li> <li>20 Compartments T, Se</li> <li>21 Circuit interrupter</li> <li>22 Right crew couch</li> <li>23 Crew attenuation str</li> <li>24 Side shock attenuati</li> <li>25 Waste storage inter i</li> <li>26 Stowed fecal caniste</li> <li>27 Sanitation supply sh</li> <li>28 Scientific equipment</li> <li>29 Battery charger (ref)</li> </ul>
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GENERAL INFORMATION



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Figure 1-6. C/M Equipment and Stowage Bays

SPACECRAFT 012 CONFIGURATION

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1.1.2.6 Food and Water.

Food and water provisions, including water delivery and food preparation equipment, are available in the crew compartment LHEB and LEB (figure 1-6) for the length of the mission. Food may be prepared by adding water to plastic bags containing the dehydrated food and kneading the mixture. Prepared food can be squeezed directly into the mouth of an astronaut. Hot or cold water is available at the potable water supply panel for food reconstitution. Chilled drinking water is supplied to the crew through a flexible hose from the water delivery unit. The potable water is a by-product of the EPS fuel cells.

1.1.2.7 Waste Management.

Waste management provisions in the crew compartment RHFEB and AESB (figure 1-6) consist of equipment for collecting, sterilizing, and storing human fecal matter and personal hygiene wastes (such as used cleansing pads, towels, etc.). Fecal matter and personal hygiene wastes are collected in polyethylene bags, disinfected, and stored in a vented area. Urine is expelled overboard into space.

1.1.2.8 Survival Equipment.

The survival kits stowed in the crew compartment RHFEB (figure 1-6) are available for the postlanding phase of the mission (land or water). The major items contained in each kit include 6 pounds of water, a desalter kit, a one-man life raft, radio transceiver, portable light, sunglasses, and a machete. Life vests worn by the crew during lift-off and entry are stowed in the space suit stowage bag during the orbit phase of the mission. (See figure 1-6.)

1.1.2.9 Aft Compartment.

The aft compartment (figure 1-3) is the area encompassed by the aft portion of the crew compartment heat shield, aft heat shield, and aft portion of the primary structure. This compartment contains 10 reaction control engines, an impact attenuation structure, instrumentation, and storage tanks for water, fuel, oxidizer, and gaseous helium. (Four crushable ribs, along the S/C +Z axis, are provided as part of the impact attenuation structure to absorb energy during a land impact.)

The aft heat shield, which encloses the large end of the C/M, is a shallow spherically contoured assembly. It is made of the same type of materials as other C/M heat shields. However, the ablative material on this heat shield has a greater thickness for the dissipation of heat during entry. External provisions are made on this heat shield for connecting the C/M to the S/M.

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SPACECRAFT 012 CONFIGURATION

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1.1.3 SERVICE MODULE.

The S/M is a cylindrical structure formed by 1-inch-thick aluminum honeycomb panels. Radial beams, from milled aluminum alloy plates, separate the structure interior into six unequal sectors around a circular center section. (See figure 1-7.) Equipment contained within the service module is accessible through maintenance doors located strategically around the exterior surface of the module. Specific items, such as flight control system (SPS and RCS) and most of the S/C on-board consumables (and storage tanks) contained in the S/M compartments, are listed in figure 1-7.

Radial beam trusses on the forward portion of the S/M structure (figure 1-7) provide a means for securing the C/M to the S/M. Alternate beams, one, three, and five, have compression pads for supporting the C/M. Beams two, four, and six, have shear-compression pads, and tension ties. A flat center section in each tension tie incorporates redundant explosive charges for S/M-C/M separation. These beams and separation devices are enclosed within a fairing (26 inches high and 13 feet in diameter) between the C/M and S/M.

1.1.4 SPACECRAFT LEM ADAPTER.

The spacecraft LEM adapter (SLA) is a truncated cone which connects the CSM to the S-IVB instrument unit on the launch vehicle. (See figure 1-1.) This adapter, constructed of eight 2-inch-thick aluminum panels, is 154 inches in diameter at the forward end (C/M interface) and 260 inches at the aft end. Separation of the spacecraft from the SLA is accomplished by means of explosive charges which permit the four SLA forward panels (above station 583.3), to disengage from the CSM and rotate outward 45 degrees from vertical. The four aft panels remain attached to the S-IVB instrument unit. For mission 204A, a cross-shaped stiffener is installed within the SLA in place of a LEM. The S/M SPS nozzle extends into the SLA which also houses an umbilical cable for connecting circuits between the launch vehicle and the spacecraft.

1.1.5 SPACECRAFT SYSTEMS.

Data relating to the operational spacecraft systems and interface information are presented in section 2 of this handbook.

1.2 LAUNCH VEHICLE CONFIGURATION.

A two-stage Saturn IB launch vehicle, consisting of an S-IB booster and an S-IVB second stage, is scheduled to provide the required thrust for inserting S/C 012 into orbit (figure 1-8.) An instrumentation unit, located between the S-IVB and the SLA, controls each of the two boost stages during flight. The total length of the Saturn IB launch vehicle, including the spacecraft, is approximately 224 feet. An emergency detection system sequencer display panel, in the C/M, enables the crew to monitor launch vehicle engine performance during lift-off. (Refer to the sequential systems in section 2.)

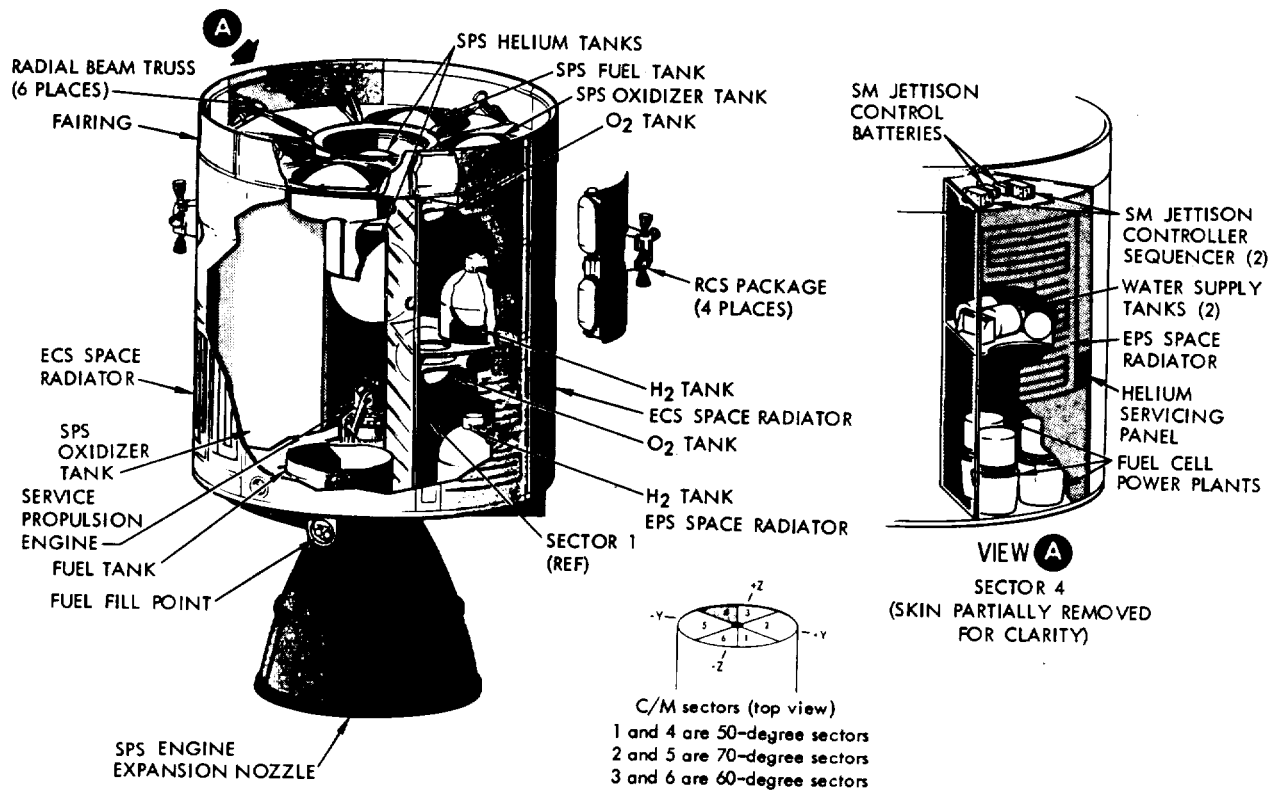
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SPACECRAFT 012 CONFIGURATION—LAUNCH VEHICLE CONFIGURATION



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SERVICE MODULE ITEMS

<p>Sector 1</p> <ul style="list-style-type: none"> <li>Electrical power system space radiator</li> <li>Super-critical oxygen tank (two)</li> <li>Super-critical hydrogen tank (two)</li> </ul> <p>Sector 2</p> <ul style="list-style-type: none"> <li>Environmental control system space radiator</li> <li>Service propulsion system oxidizer tank</li> <li>Reaction control system package (+Y-axis)</li> <li>Space radiator isolation valve (two)</li> </ul> <p>Sector 3</p> <ul style="list-style-type: none"> <li>Service propulsion system fuel tank</li> <li>Reaction control system package (+Z-axis)</li> <li>Service propulsion system helium tanks (two)</li> </ul> <p>Sector 4</p> <ul style="list-style-type: none"> <li>Electrical power system space radiator</li> <li>Fuel cell power plant (three)</li> <li>Helium servicing panel</li> <li>Reaction control system control unit</li> <li>Electrical power system power control relay box</li> <li>Service module jettison control battery (two)</li> <li>Service module jettison controller sequencer (two)</li> <li>Water supply tank (two)</li> </ul>	<p>Sector 5</p> <ul style="list-style-type: none"> <li>Environmental control system space radiator</li> <li>Service propulsion system oxidizer tank</li> <li>Reaction control system package (-Y axis)</li> </ul> <p>Sector 6</p> <ul style="list-style-type: none"> <li>Space radiator selection valve, (two)</li> <li>Glycol shutoff valves (two)</li> <li>Reaction control system package (-Z axis)</li> <li>Service propulsion system fuel tank</li> </ul> <p>Center section</p> <ul style="list-style-type: none"> <li>Service propulsion system helium tank (two)</li> <li>Service propulsion system engine</li> </ul>
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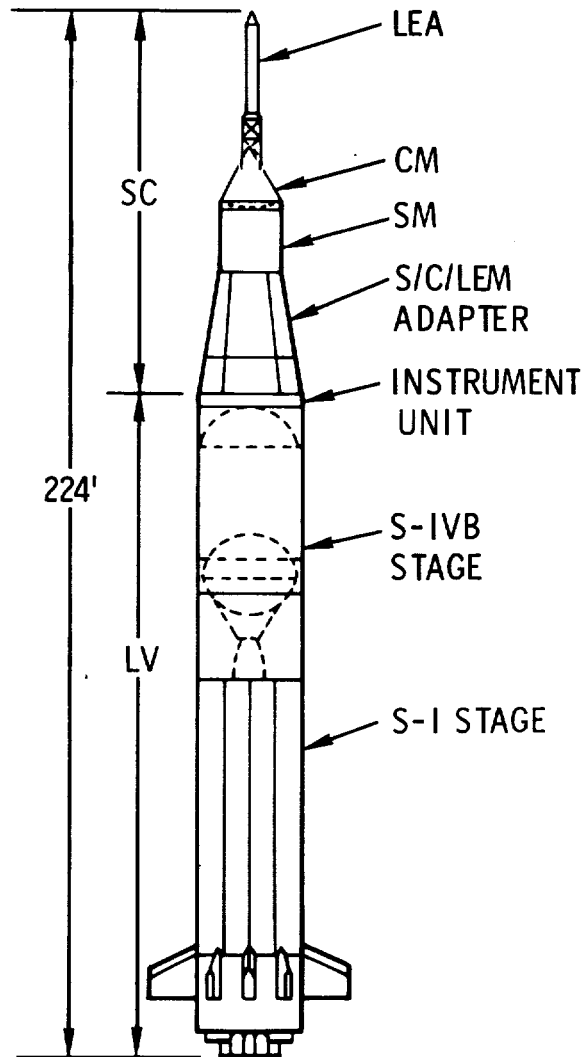
Figure 1-7. Spacecraft 012 Service Module

SPACECRAFT 012 CONFIGURATION

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Figure 1-8. Apollo Launch Vehicle (Saturn IB)

LAUNCH VEHICLE CONFIGURATION

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1.2.1 S-IB BOOSTER.

The S-IB booster (first stage) for Saturn IB is manufactured by the Chrysler Corporation. This booster is 257 inches in diameter, 82 feet in length, and is powered by eight Rocketdyne H-1 engines. Each engine, burning RP-1 and liquid oxygen, produces 200,000 pounds of thrust for a total stage thrust over 1,600,000 pounds.

1.2.2 S-IVB SECOND STAGE.

The S-IVB second stage for Saturn IB is manufactured by the Douglas Aircraft Company. This stage is 260 inches in diameter, 58 feet in length, and is powered by a single Rocketdyne J-2 engine. The engine, burning liquid hydrogen and oxygen, produces a stage thrust of approximately 200,000 pounds. During flight, the J-2 engine uses three different mixture ratios, resulting in values of thrust ranging from 190,000 to 230,000 pounds.

1.3 MISSION 204A WEIGHT STATUS.

**NOTE** The NASA-MSD is responsible for providing a detailed weight status for Apollo mission 204A as available in the MSD Reference Trajectory Document.

1.4 POSTLANDING AND RECOVERY.

Information relating to postlanding recovery aids is provided under sequential systems in section 2. Postlanding ventilation for the crew is supplied through two vent valves in the forward access hatch cover. (See figure 1-4.) A handpump and flexible hose, stored under the right crew couch (figure 1-6), is used to obtain water from the sea for conversion to potable water. (Refer to crew equipment in section 6.) An Apollo Recovery Operations Handbook will provide a detailed description of recovery equipment and rescue procedures.



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SYSTEMS DATA

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SECTION 2  
SYSTEMS DATA

INTRODUCTION.

Systems data include description of operations, component description and design data, operational limitations and restrictions, and telemetry measurements. Subsection 2.1 describes the overall spacecraft navigation, guidance, and control requirements and the resultant systems interface. Subsections 2.2 through 2.10 present data grouped by spacecraft systems, arranged in the following order: guidance and navigation, stabilization and control, service propulsion, reaction control, electrical power, environmental control, telecommunications, sequential, and cautions and warnings. Subsection 2.11 deals with miscellaneous systems data.



SYSTEMS DATA

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SECTION 2

SUBSECTION 2.1

GUIDANCE AND CONTROL

2.1.1 SYSTEMS INTERFACE, GUIDANCE AND CONTROL.

Apollo CSM atmospheric and space flight is achieved by application of controlled translation forces and rotational force moments. Guidance and control initiates and terminates the thrust and rotational forces and force moments as a function of the magnitude of the change required. Guidance and control provides the following basic functions:

- Attitude Control
- Guidance
- Navigation

Attitude control is a function associated with spacecraft orientation with respect to an inertial reference or a known coordinate system. Guidance is a function requiring a combination of attitude control with rate stabilization and steering commands for the purpose of modifying spacecraft trajectory via major velocity changes. Navigation determines spacecraft position and velocity, and predicts future position.

To accomplish mission requirements, the guidance and navigation, stabilization and control, service propulsion, and reaction control systems, plus the astronauts, are integrated into an automatic/manual closed loop control system.

Guidance and control activity is grouped into three profiles of flight: coasting, powered, and atmospheric. The primary control loops involved are illustrated in figures 2.1-1 through 2.1-4. Figure 2.1-1 is an abbreviated integration of all major equipments necessary to accomplish the activities in all three flight profiles. Figures 2.1-2 through 2.1-4 divide the equipment into the proper perspective for each profile.

It must be noted that in figure 2.1-1, the loops are closed that represent coasting flight (CF) functions. For powered flight (PF) or atmospheric flight (AF), open the coasting flight loops and close contacts representing the desired loops.

2.1.2 COASTING FLIGHT

The guidance and control activities involved in coasting flight are accomplished through the basic functional loops shown in figure 2.1-2.

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GUIDANCE AND CONTROL

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SYSTEMS DATA

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These loops provide attitude reference, attitude control, attitude hold, and automatic and manual maneuver capabilities necessary to accomplish the several tasks involved during coasting flight. They are also the central reference and control loops required for all phases of flight.

A reference attitude frame is established by the G&N inertial measurement unit (IMU), and/or by the SCS body-mounted attitude gyros (BMAGs), and attitude gyro coupling unit (AGCU). Inertial sensors sense S/C motion contrary to the reference frame. The sensed attitude errors and rates are conditioned through servo electronics and logic to initiate countermotions via the reaction jet control (RCS) which nullifies the original motion. The AGC inserts automatic control and maneuver commands into the loop. The rotation, translation, and attitude impulse controls insert manual commands into the loop. The flight director attitude indicator (FDAI) is the S/C attitude visual display.

2.1.3 POWERED FLIGHT.

Powered flight is considered that which will use the S/M service propulsion system (SPS) engine to initiate a major velocity change. Figure 2.1-3 illustrates those basic loops necessary for the tasks involved. As shown, the loops are an extension of those required for coasting flight. Added, are the (SPS) engine on-off thrust logic and the SPS gimbal control loops. In coasting flight, all attitude control is through the RCS. Powered flight, by the SPS engine, requires roll control through the RCS, and pitch and yaw control by gimbaling the SPS engine nozzle. Primary control of thrusting is by the AGC. However, figure 2.1-3 shows how various manual controls can be used instead of or to backup automatic functions.

2.1.4 ATMOSPHERIC FLIGHT

Atmospheric flight is encountered during the entry phase of the mission at which time the S/C experiences aerodynamic forces. Figure 2.1-4 illustrates the basic loops required for control of the S/C during this phase. The central loop is identical to that in figure 2.1-2. The main difference is that service module/command module (S/M-C/M) separation has taken place, and the command module RCS system is used. Another difference is that the aerodynamic forces will stabilize the C/M in pitch and yaw, and the entry g-level (lift vector control) will increase or decrease through roll control. Primary control is automatic, with manual rotation control available, in event of automatic control malfunctions.

For detailed operation of the several loops involved in guidance and control, refer to the descriptions of the guidance and navigation system, subsection 2.2, and the stabilization and control system, subsection 2.3.

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GUIDANCE AND CONTROL



GUIDANCE AND CONTROL

GUIDANCE AND NAVIGATION SYSTEM

STABILIZATION AND CONTROL SYSTEM

SERVICE PROPULSION SYSTEM

REACTION CONTROL SYSTEM

ELECTRICAL POWER SYSTEM

ENVIRONMENTAL CONTROL SYSTEM

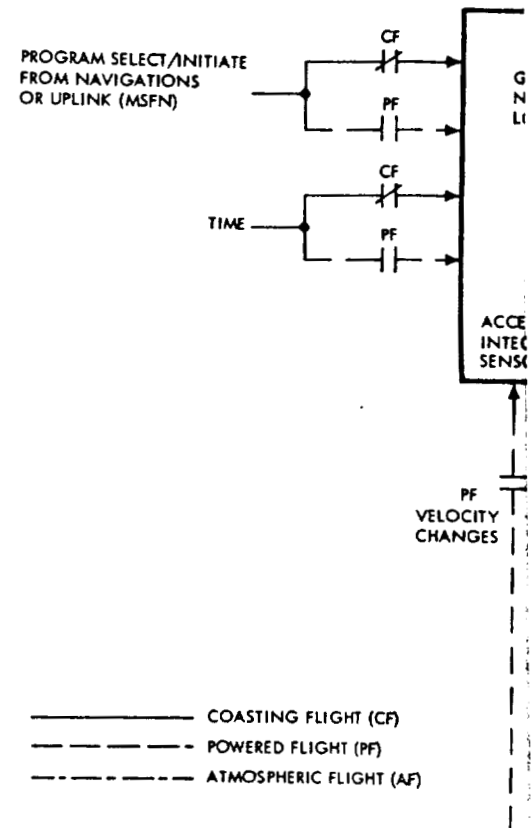
TELECOMMUNICATION SYSTEM

SEQUENTIAL SYSTEMS (SECS, EDS, LES, ELS)

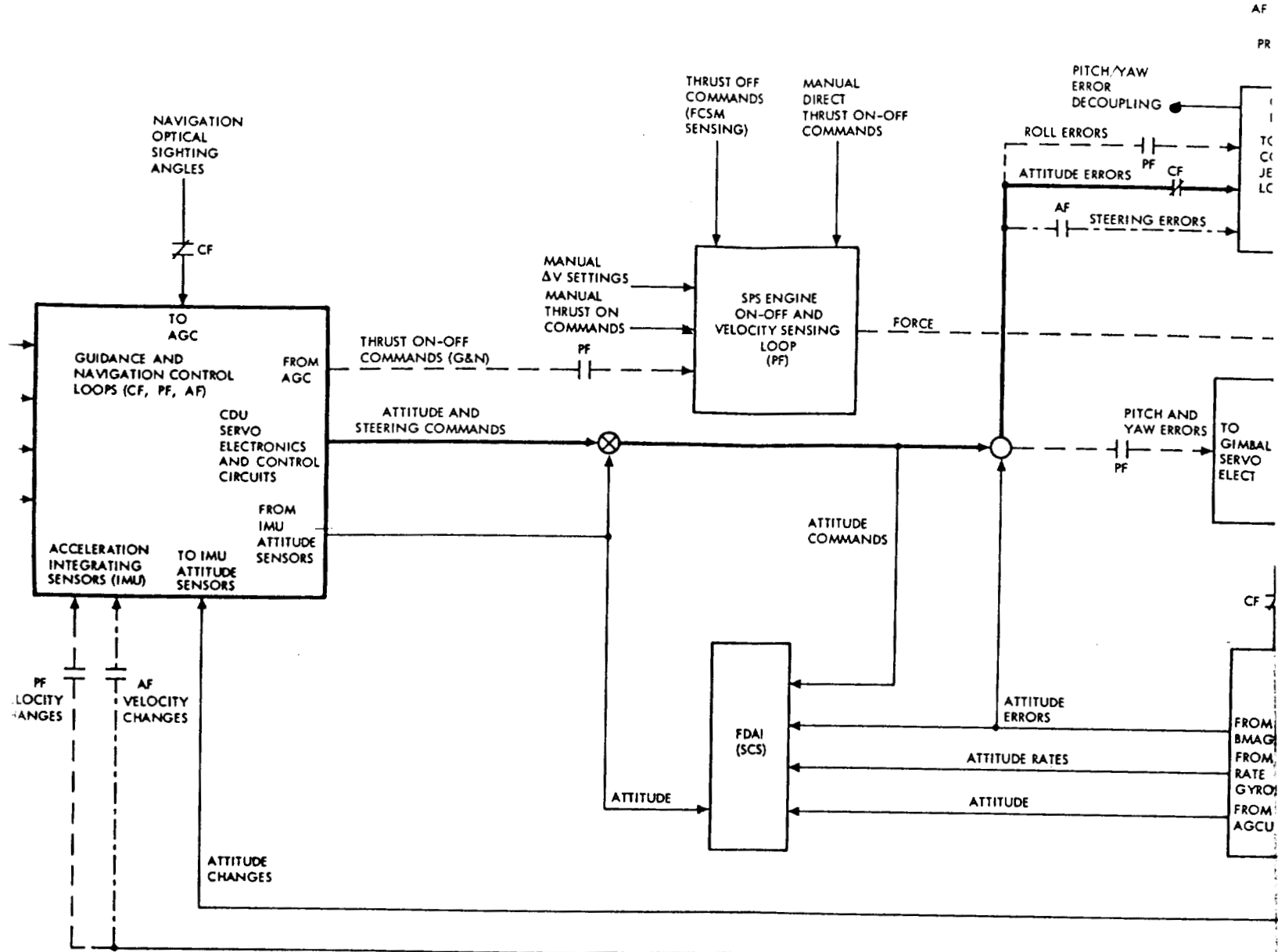
CAUTION AND WARNING SYSTEM

MISCELLANEOUS SYSTEMS DATA



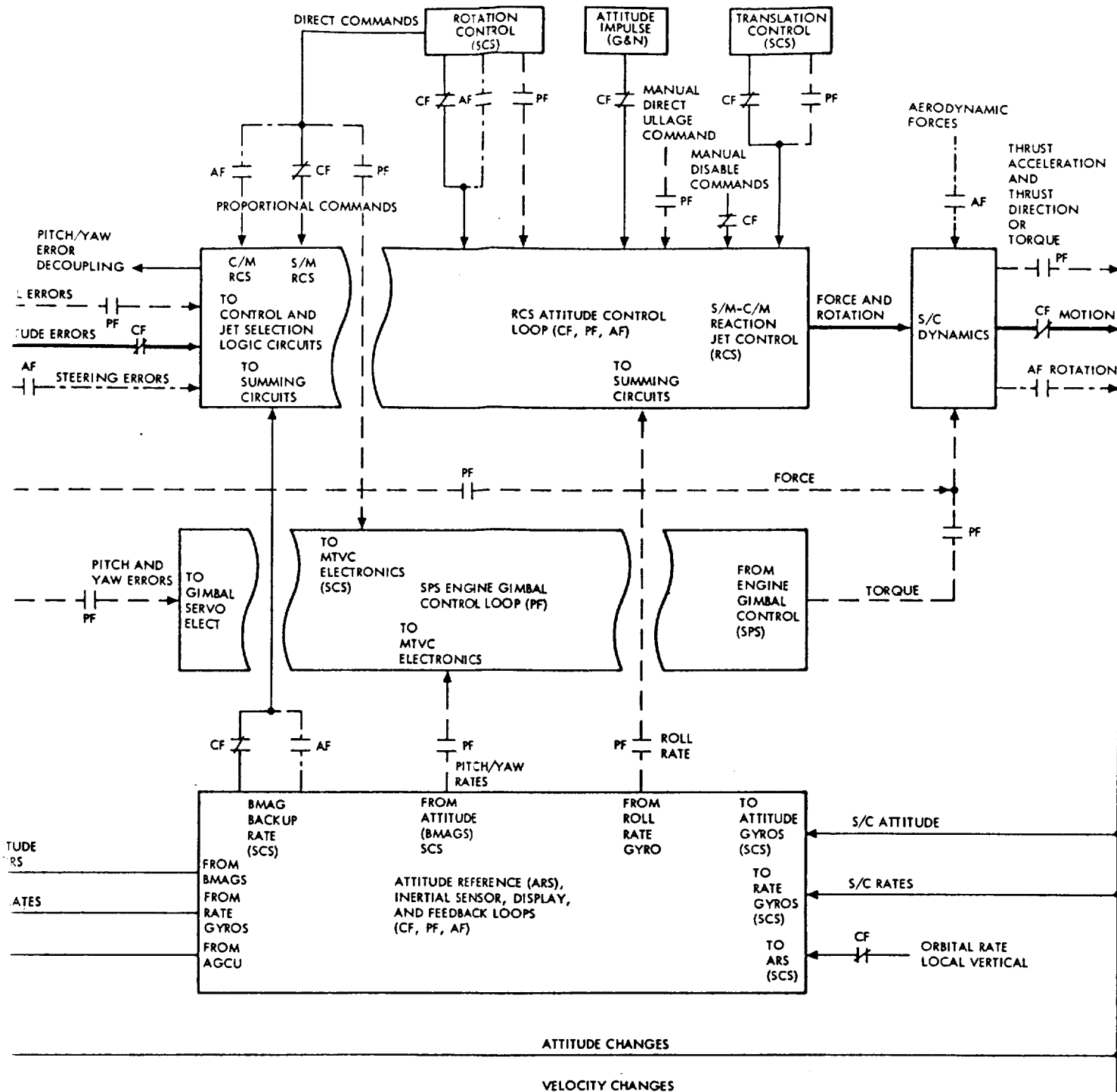


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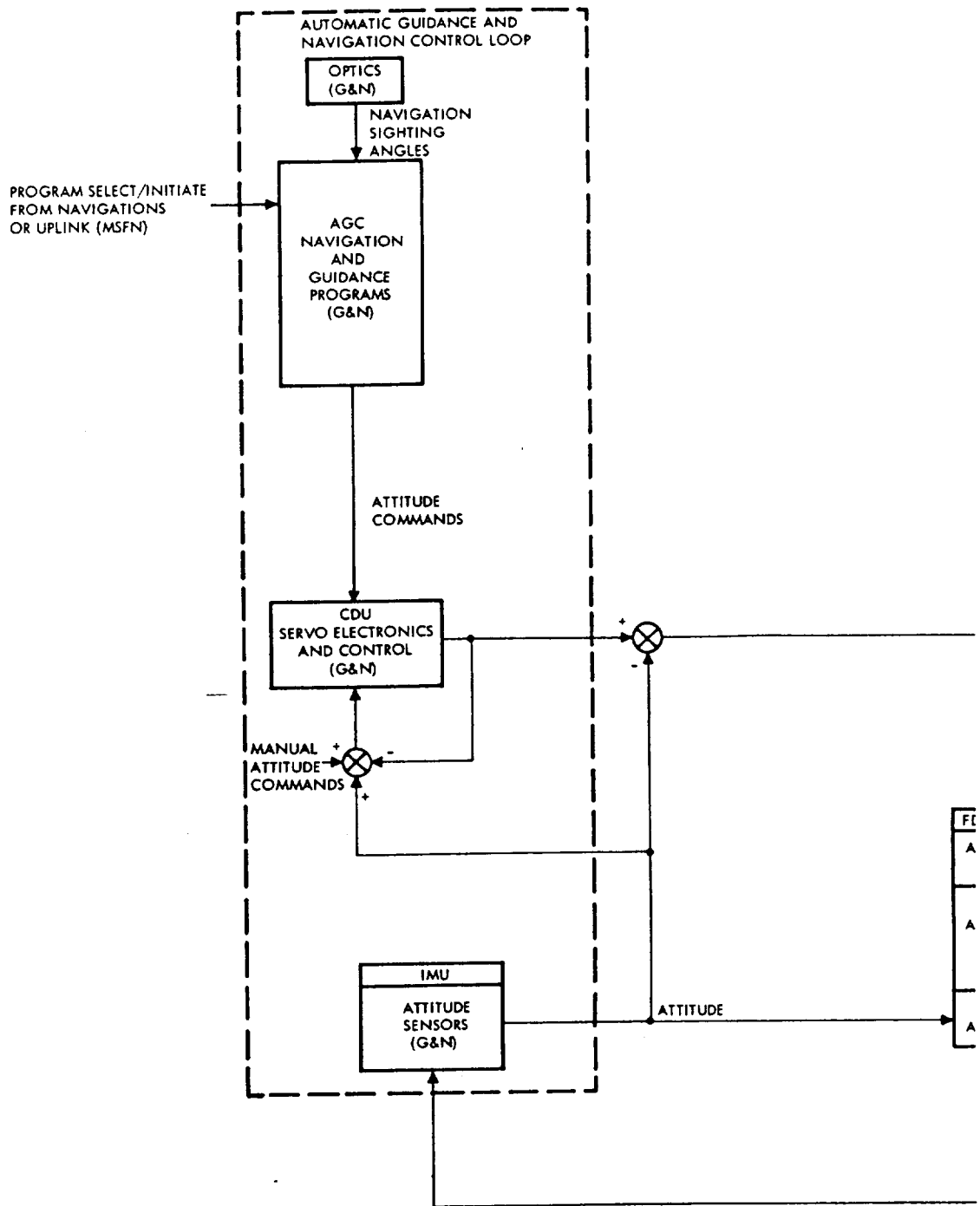
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Figure 2.1-1. Integrated Flight Profile Functional Flow Diagram

GUIDANCE AND CONTROL

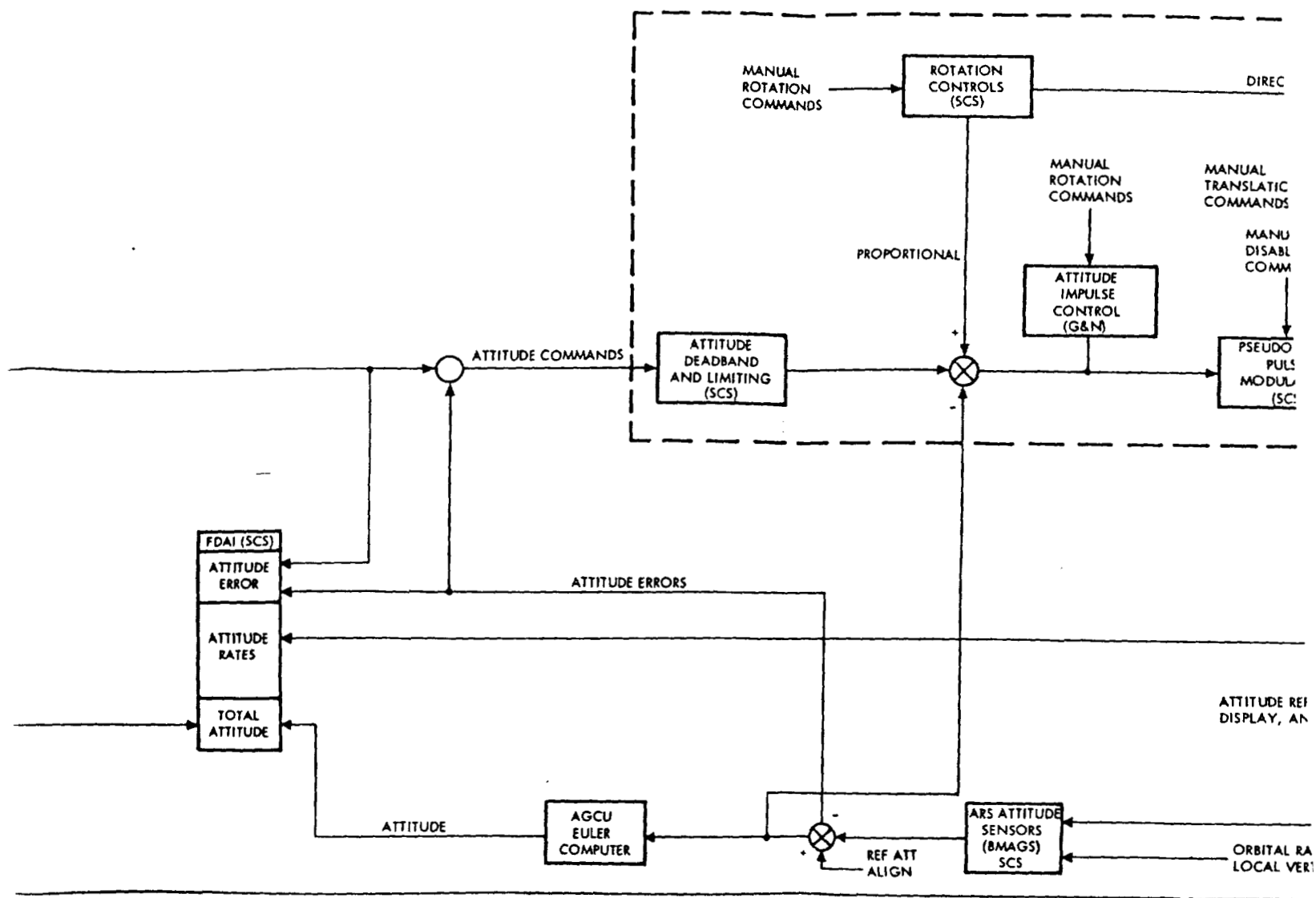






**SOLDOUT FRAME**

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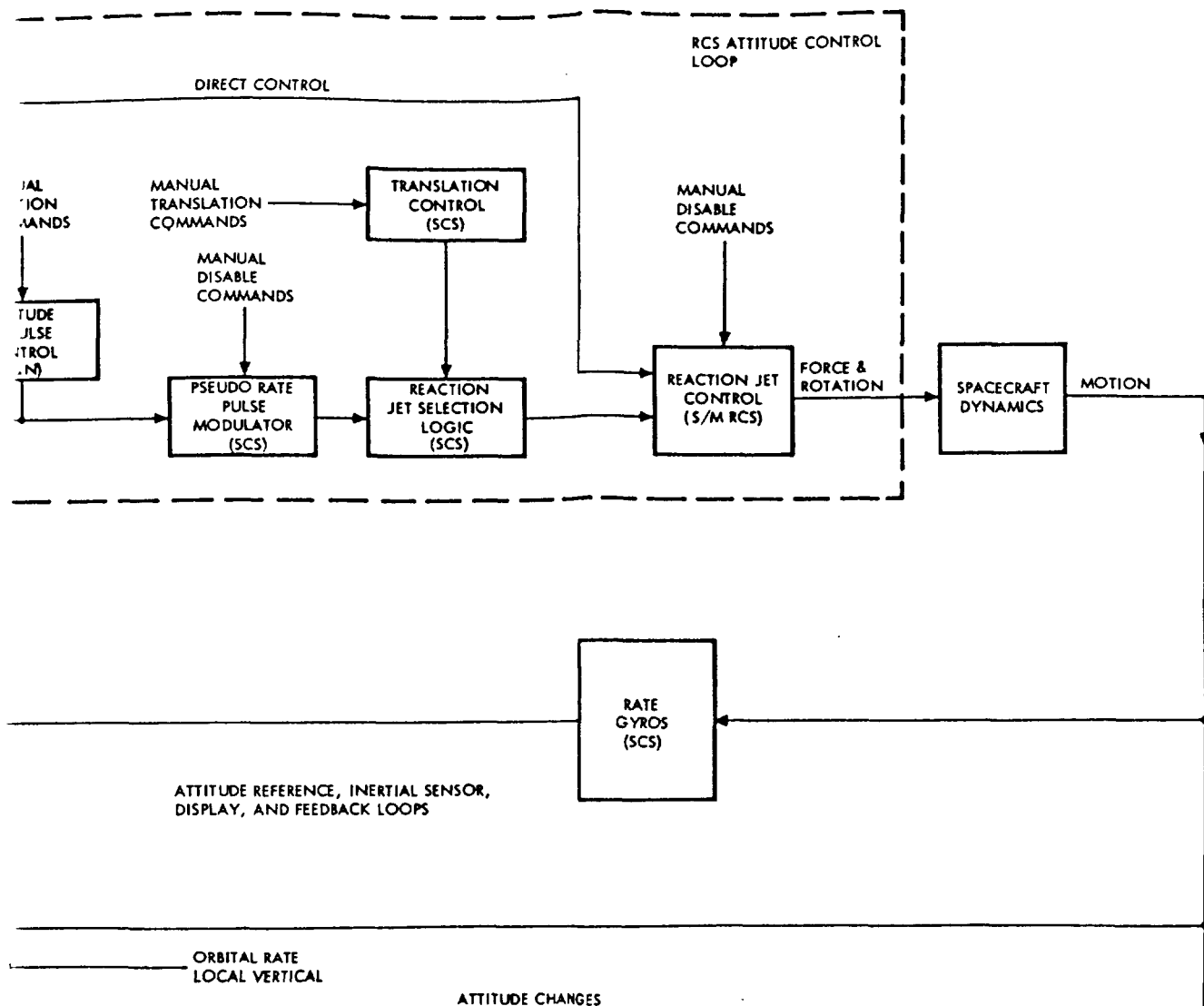
**BOLDOLT REFAME**

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Mission.



SYSTEMS DATA



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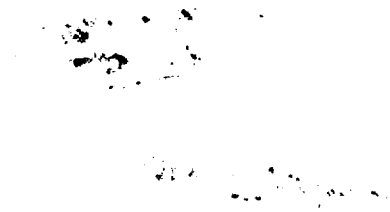
Figure 2.1-2. Casting Flight Profile Functional Flow Diagram

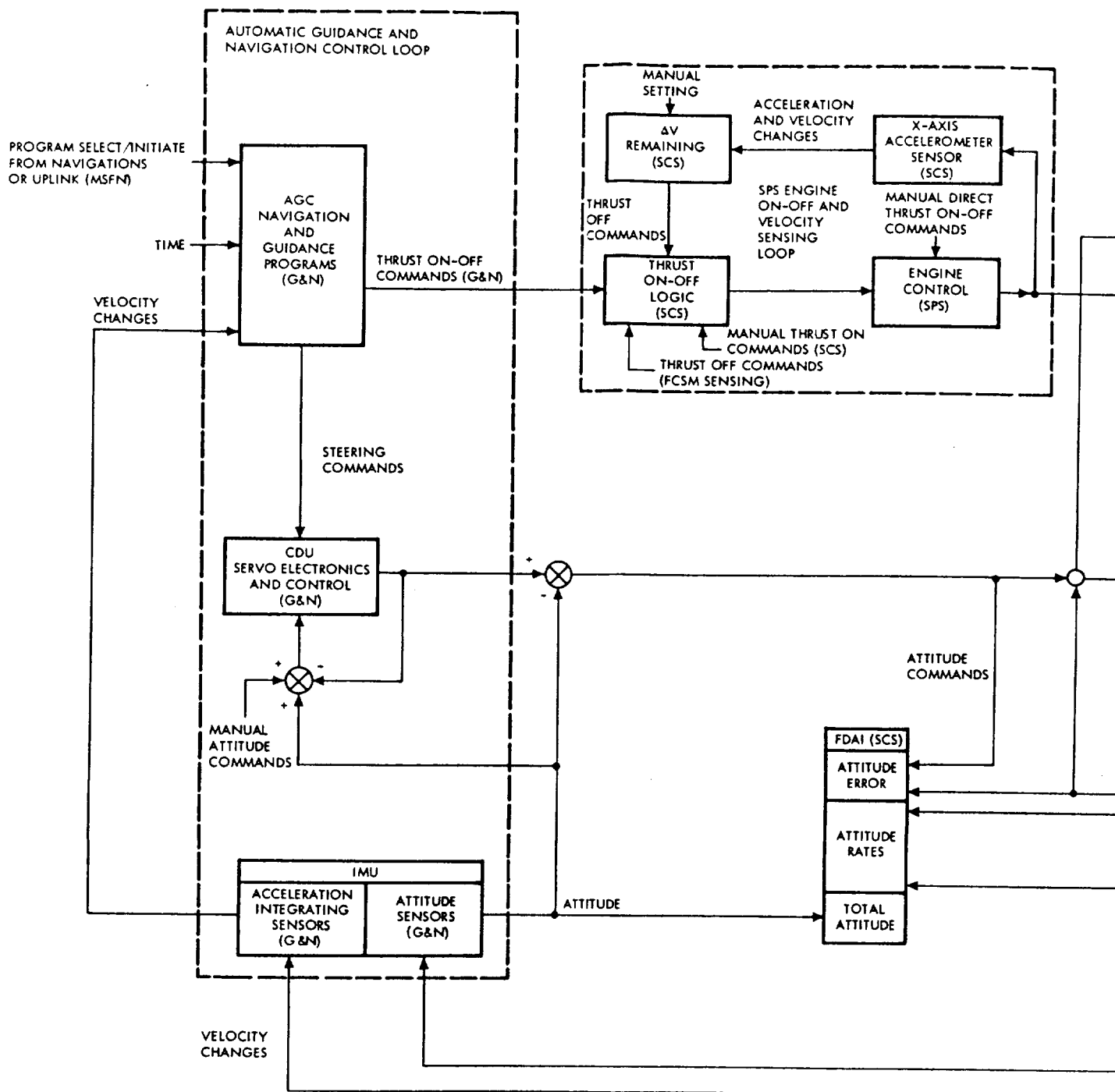
GUIDANCE AND CONTROL

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**SOLDOUT**





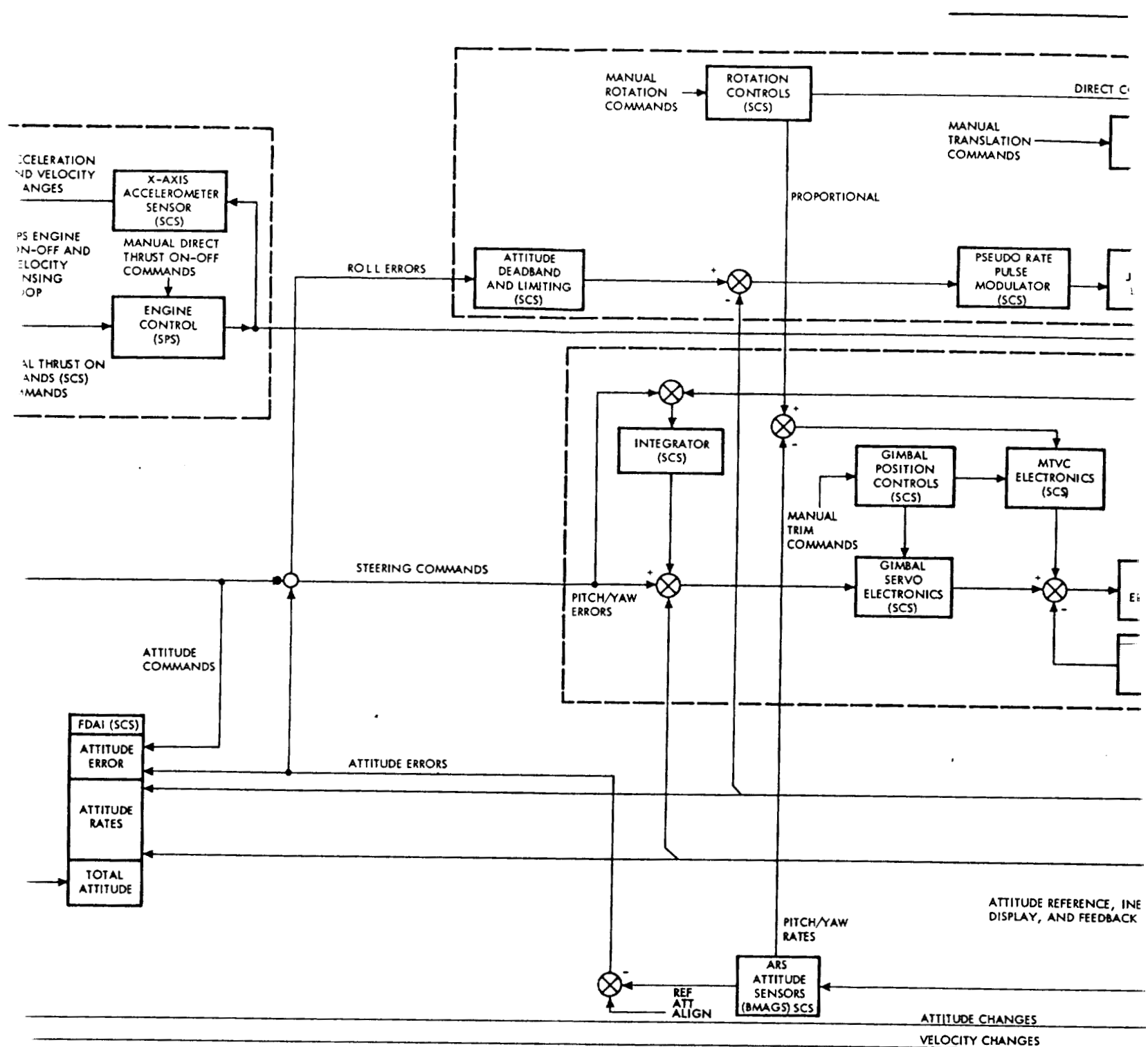


Figure 2.

FOLDOUT 2

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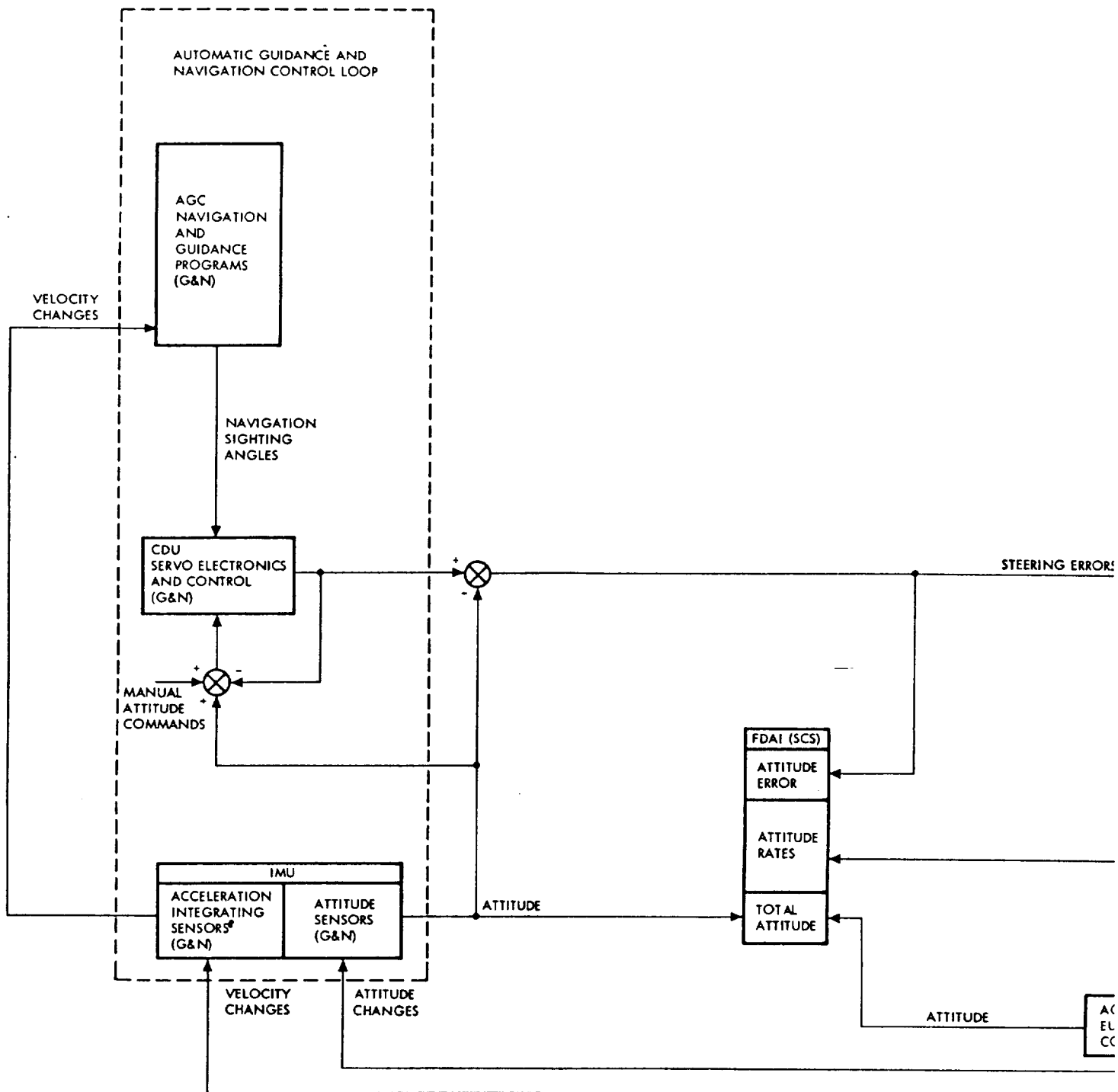
10/10/2020 10:10:10 AM  
 10/10/2020 10:10:10 AM  
 10/10/2020 10:10:10 AM

The diagram illustrates the RCS attitude control system architecture, organized into three main functional areas:

- DIRECT CONTROL:** This section at the top left handles manual inputs. It includes a block for **MANUAL TRANSLATION COMMANDS** feeding into **TRANSLATION CONTROL (SCS)**. This block then feeds into **REACTION JET SELECTION LOGIC (SCS)**. A **PSEUDO RATE PULSE MODULATOR (SCS)** also feeds into the selection logic. The selection logic outputs to the **REACTION JET CONTROL (S/M RCS)** block.
- RCS ATTITUDE CONTROL LOOP:** This central loop receives a **MANUAL DIRECT ULLAGE COMMAND** and the output from the **REACTION JET CONTROL (S/M RCS)** block. It outputs **FORCE AND ROTATION** signals to the **SPACECRAFT DYNAMICS** block.
- SPACECRAFT DYNAMICS:** This block receives inputs from the RCS loop and provides feedback signals: **THRUST ACCELERATION AND THRUST DIRECTION OR TORQUE** (outputting to the right), **FORCE** (feeding back into the RCS loop), and **TORQUE** (feeding into the SPS engine gimbal control loop).
- SPS ENGINE GIMBAL CONTROL LOOP:** This bottom section manages the gimbal positioning. It receives **TORQUE** from the spacecraft dynamics. The loop includes:
  - GIMBAL POSITION SENSORS (SPS)** and **GIMBAL RATE SENSORS (SPS)** providing feedback.
  - GIMBAL POSITION CONTROLS (SCS)** and **GIMBAL SERVO ELECTRONICS (SCS)** processing position commands.
  - MTVC ELECTRONICS (SCS)** and **GIMBAL CONTROL ELECTRONICS (SCS)** processing rate feedback.
  - ENGINE GIMBAL CONTROL (SPS)** which outputs **TORQUE** back to the spacecraft dynamics.
- ATTITUDE REFERENCE, INERTIAL SENSOR, DISPLAY, AND FEEDBACK LOOPS:** This bottom section receives **ATTITUDE CHANGES** and **VELOCITY CHANGES** as inputs. It feeds into a **RATE GYROS (SCS)** block, which outputs **R, P, Y** (roll, pitch, yaw) rates to the **REACTION JET SELECTION LOGIC (SCS)** in the Direct Control section.

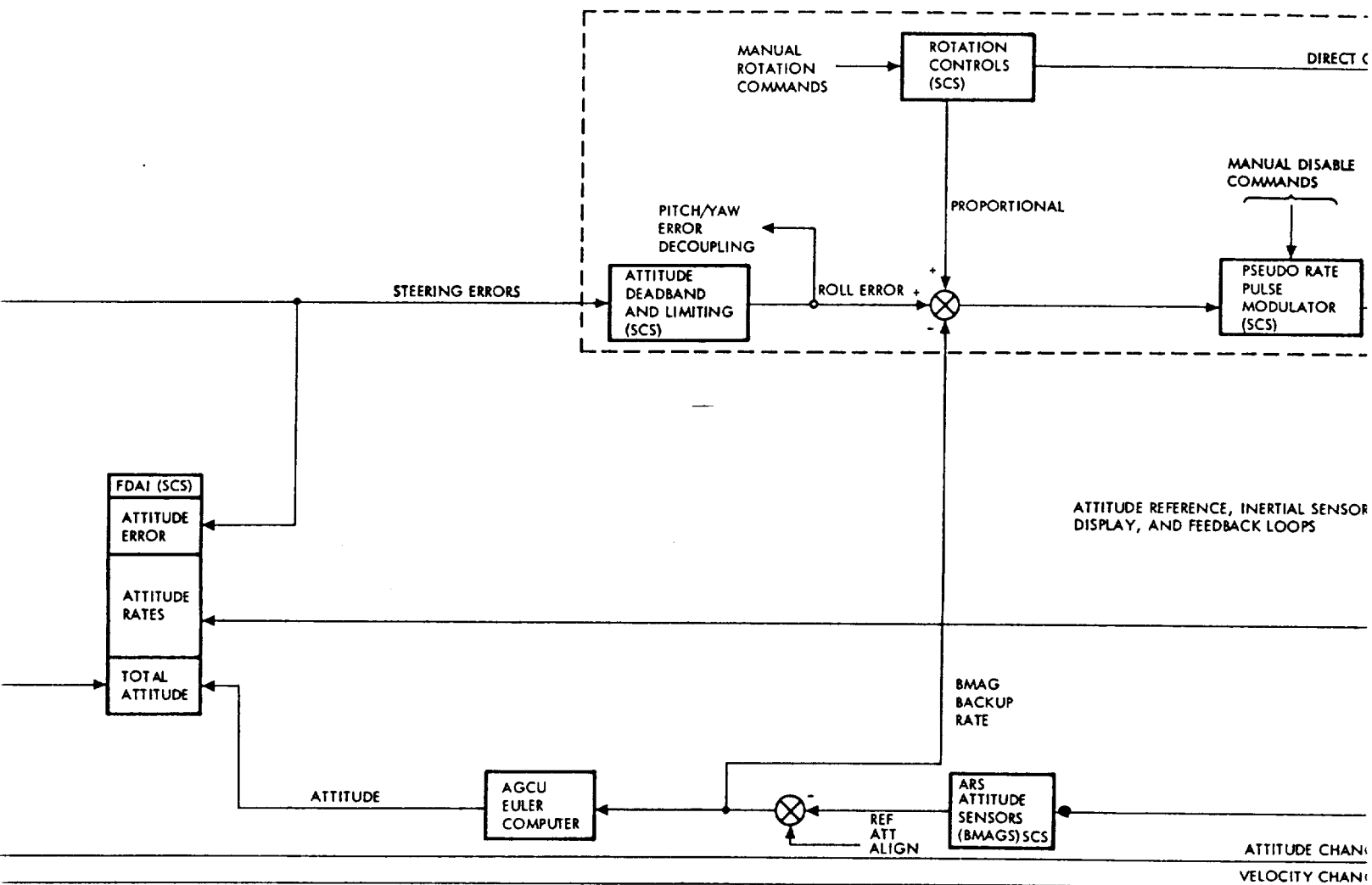
**GOLDOLITE FRAME**





(FOLDOUT FRAME)





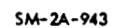
Figure

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Mission







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**GOLDONI FRAME 3**

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SYSTEMS DATA

G&N

SECTION 2

SUBSECTION 2.2

GUIDANCE AND NAVIGATION SYSTEM (G&N)

2.2.1 INTRODUCTION.

The guidance and navigation (G&N) system measures spacecraft attitude and velocity, determines trajectory, controls spacecraft attitude, controls the thrust vector of the service propulsion engine, and provides abort information and display data. Primary determination of the spacecraft velocity and position, and computation of the trajectory parameters is accomplished by the manned space flight network (MSFN).

The G&N system consists of three subsystems as follows:

- Inertial subsystem (ISS)
- Computer subsystem (CSS)
- Optics subsystem (OSS)

The inertial subsystem is composed of an inertial measurement unit (IMU), part of the power and servo assembly (PSA), part of the controls and displays, and three inertial coupling display units (CDUs). The IMU provides an inertial reference with a gimbaled, three-degree-of-freedom, gyro stabilized stable platform.

The computer subsystem is composed of an Apollo guidance computer (AGC), and two display and keyboard panels (DSKYs), which are part of the controls and displays. The AGC is a digital computer which processes and controls information to and from the IMU and optics, and stores programs and reference data.

The optics subsystem is composed of a scanning telescope (SCT), a sextant (SXT), drive motors for positioning the SCT and SXT, parts of the PSA, part of the controls and displays, and two optics CDUs. The SCT and SXT are used to determine the spacecraft position and attitude with relation to stars and/or landmarks.

The three G&N subsystems are configured such that the CSS and OSS may be operated independently. This allows continued use of the CSS and/or OSS in the event of a malfunction in one of these subsystems or the ISS. System power requirements and reference signals are provided by the power and servo assembly (PSA). Major components of the system are located in the command module lower equipment bay (figure 2.2-1). System circuit breakers, caution and warning indicators, and one of the DSKYs are located on the main display console.

2.2.2 FUNCTIONAL DESCRIPTION.

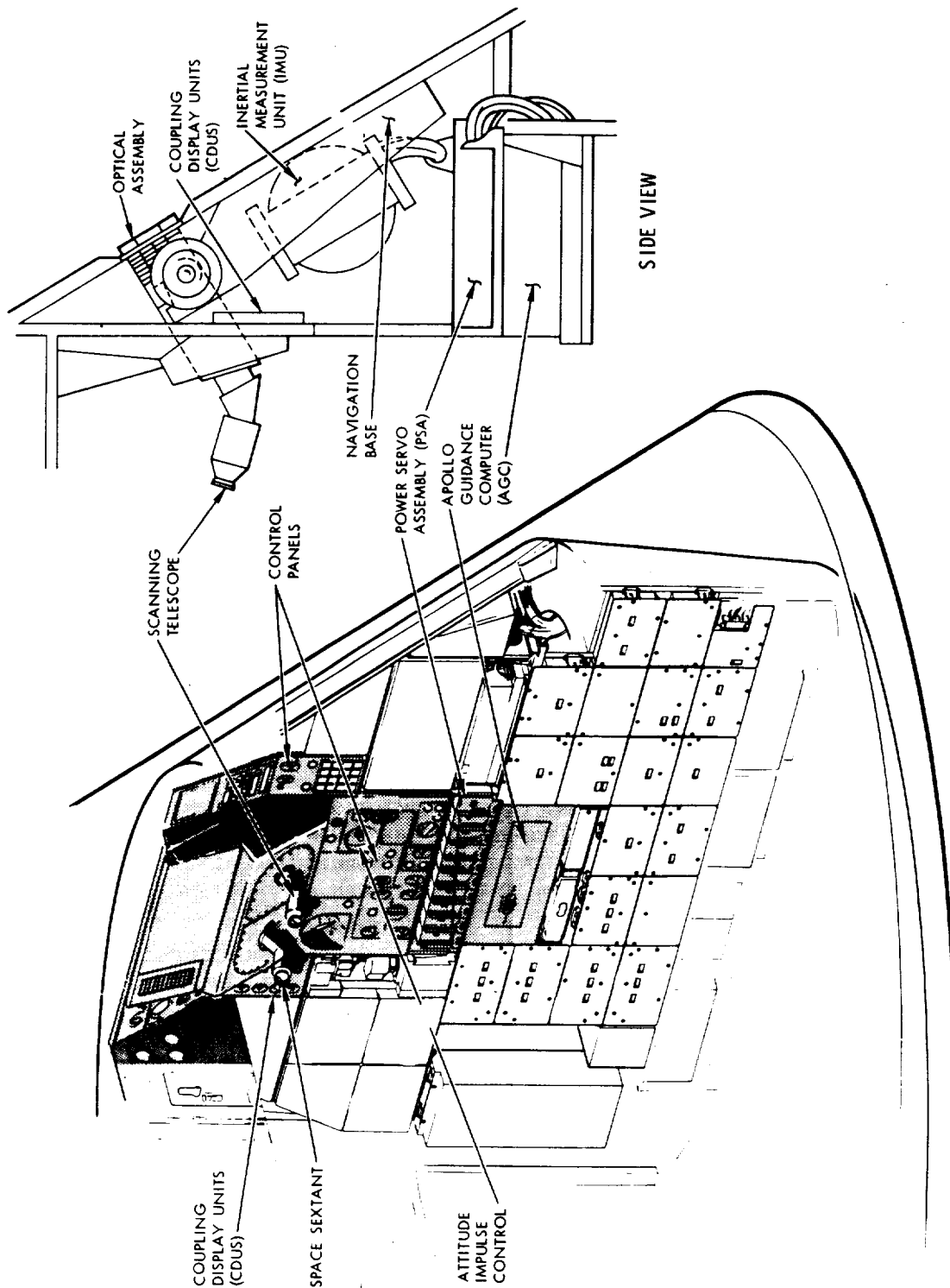
The guidance and navigation system provides capabilities for the following:

- Inertial velocity and position (state vector) computation
- Optical and inertial navigation measurements

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Figure 2.2-1. G&N Equipment Location

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- Spacecraft attitude measurement and control
- Generation of guidance commands during CSM-powered flight and C/M atmospheric entry.

The G&N system is initially activated and aligned during the prelaunch phase. During the ascent phase, the system measures velocity and attitude, computes position, compares the actual spacecraft trajectory with a pre-determined trajectory, and displays pertinent data. The flight crew uses the displayed information as an aid for decision to abort or continue the mission. However, spacecraft control is maintained by the S-IVB guidance until CSM/S-IVB separation. Upon separation, the G&N system assumes the guidance and navigation functions using the data acquired during ascent.

During periods when onboard velocity and/or attitude change sensing is not required, the IMU is placed in standby operation to conserve electrical power. The AGC is used more extensively than the IMU; however, it will also be placed in standby operation to conserve electrical power. When the guidance and navigation function is to be restored, the IMU and AGC are reactivated, with the AGC using the last computed velocity as the basis for further velocity computations. New positional data must be acquired from optical sightings or MSFN through telemetry or voice communications.

Initial position and attitude information as well as periodic updating of this information is made through use of the optics. This is accomplished by the navigator making two or more landmark and/or star sightings. The sightings are made by acquiring the star-landmark with the SCT and/or SXT. When the viewed object is centered, a mark command is initiated. The AGC reads the optics angles, IMU angles, and time, in conjunction with internal programs to determine the spacecraft position. This position information and the spacecraft velocity are used to compute an estimated trajectory. The actual trajectory is compared with previous trajectory data to generate the trajectory error, if any, for further reference. Optical measurements are also used in aligning the IMU to a specific reference orientation.

The IMU (figure 2.2-2) contains three inertial rate integrating gyros (IRIGs), three angular differentiating accelerometers (ADAs), and three pulsed integrating pendulous accelerometers (PIPAs). The IRIGs, PIPAs, and one ADA are mounted on the stable platform which is gimballed to provide three degrees of freedom. The two remaining ADAs are mounted on the middle gimbal. The stable platform inertial reference is maintained by the IRIGs and ADAs in conjunction with electronic stabilization loops. Any displacement of the platform is sensed by the IRIGs which produce output signals representative of the magnitude and direction of displacement. The ADAs sense the displacement rate and produce output rate control signals to maintain correct stabilization loop control response. The IRIG and ADA signals are applied to servo amplifiers, which condition the signals to drive gimbal torque motors. The gimbal torque motors then restore the initial platform orientation by driving the gimbals until the IRIG signals are nulled.

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The PIPAs are orthogonally mounted and sense changes in spacecraft velocity. An acceleration or deceleration results in output signals which are representative of the magnitude and direction of the velocity change. The output signals are applied to the AGC which uses the information to update spacecraft velocity data. Continual updating of velocity information, with respect to the initial spacecraft position and trajectory, enables the AGC to provide current velocity, position, and trajectory information.

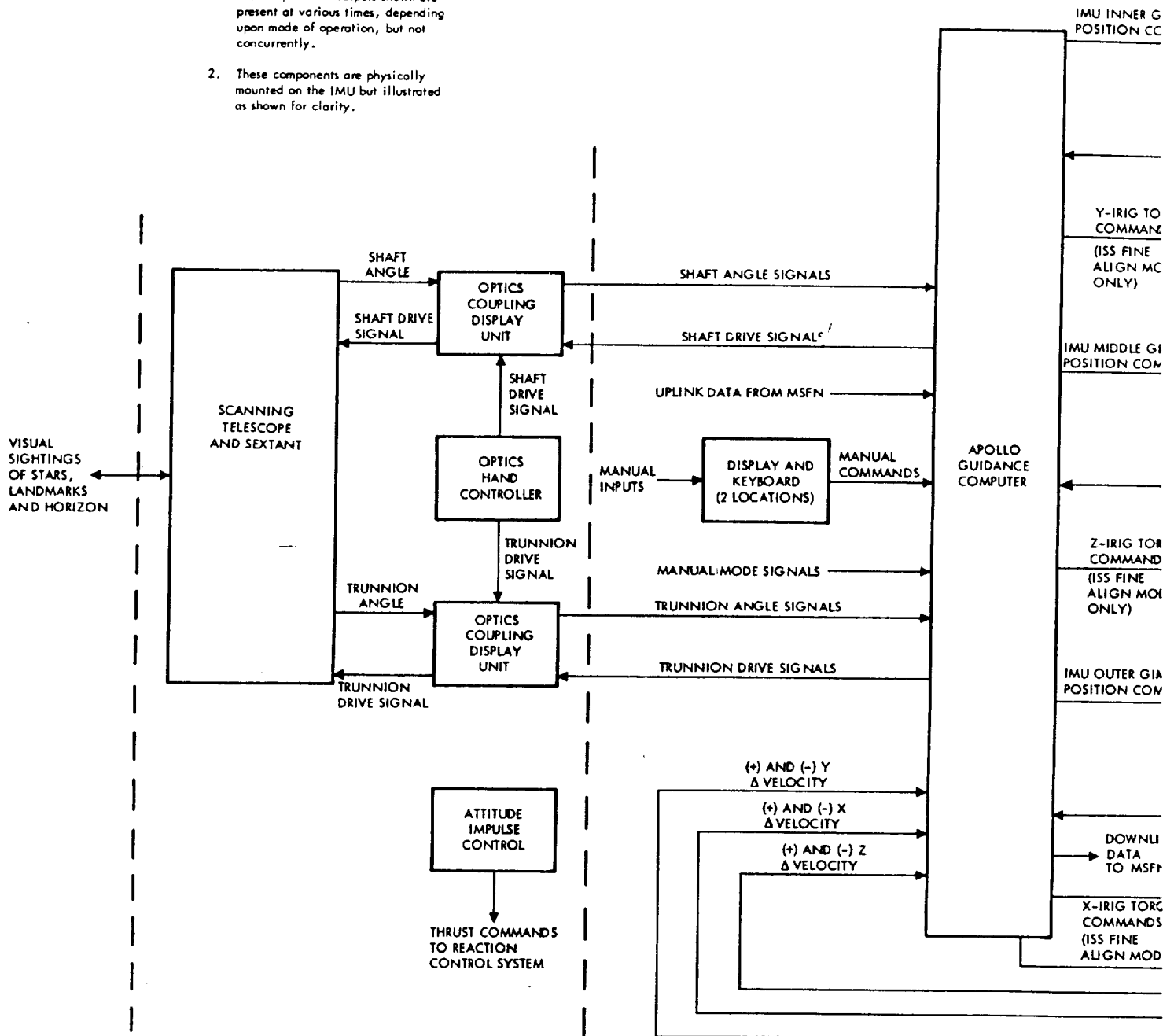
The IMU also provides a space stabilized reference for spacecraft attitude sensing and control. Attitude change sensing is accomplished by monitoring the spacecraft attitude with reference to the stable platform. Resolvers are mounted at the gimbal axes to provide signals representative of the gimbal angles. Inertial CDUs contain resolvers which repeat the platform attitude. Attitude monitoring is afforded by comparing the IMU resolver output signals with the CDU resolver signals. If the angles differ, error signals are generated and applied to the stabilization and control system. If the attitude error is larger than the selected deadband limits, the SCS fires the appropriate RCS engines. The spacecraft is rotated back to the initial reference attitude and the error signals are nulled (within deadband limits).

The AGC provides automatic execution of computer programs, automatic control of ISS and OSS modes, and, in conjunction with the DSKYs, manual control of ISS and OSS modes and computer displays. The AGC contains a two-part memory which consists of a large non-erasable section and a smaller erasable section. Non-erasable memory contains mission and system programs and other predetermined data which are wired in during assembly. Data readout from this section is non-destructive and cannot be changed during operation. The erasable section of memory provides for data storage, retrieval, and operations upon measured data and telemetered information. Data readout from this section is destructive, permitting changes in stored data to be made as desired. Information within the memory may be called up for display on the two DSKYs. The DSKYs enable the flight crew to enter data or instructions into the AGC, request display of data from AGC memory, and offer an interrupt control of AGC operation. The AGC timing section provides timing signals of various frequencies for internal use and to other onboard systems which require accurate or synchronized timing. Data within the AGC is transmitted to MSFN through a "downlink" telemetry function. Telemetered data is transmitted as a function of an AGC program or by request from MSFN. Data within the AGC may be updated through an "uplink" telemetry function controlled by MSFN. The AGC performs guidance functions by executing internal programs using predetermined trajectory parameters, attitude angles from the inertial CDUs, velocity changes from the PIPAs, and commands from the DSKYs (crew) to generate control commands. The navigation function is performed by using stored star-landmark data, optics angles from the optics CDUs, and velocity changes from the PIPAs in the execution of navigation programs.

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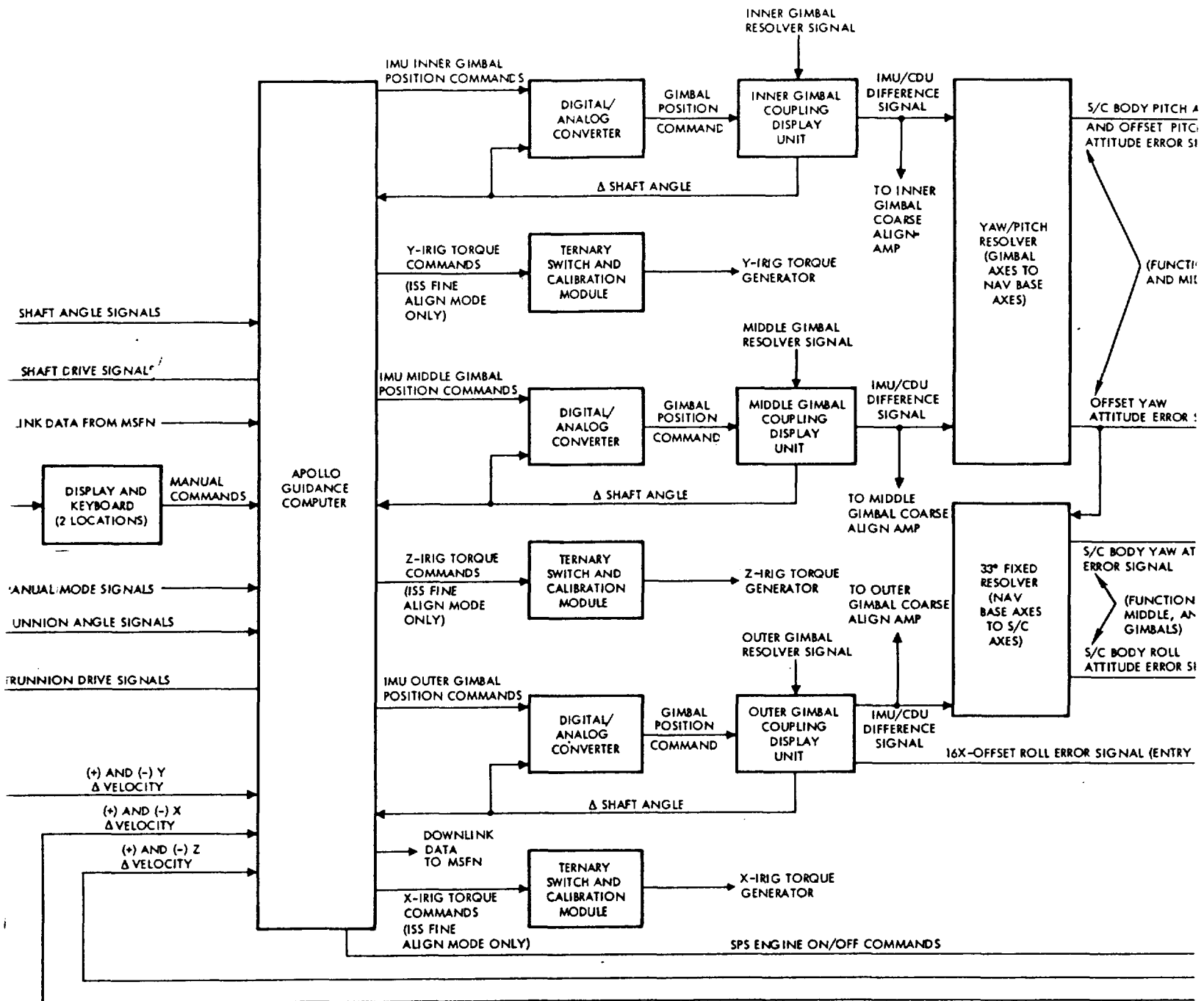
- NOTES: 1. AGC inputs and outputs shown are present at various times, depending upon mode of operation, but not concurrently.
2. These components are physically mounted on the IMU but illustrated as shown for clarity.



**SOLDOUT FRAME**



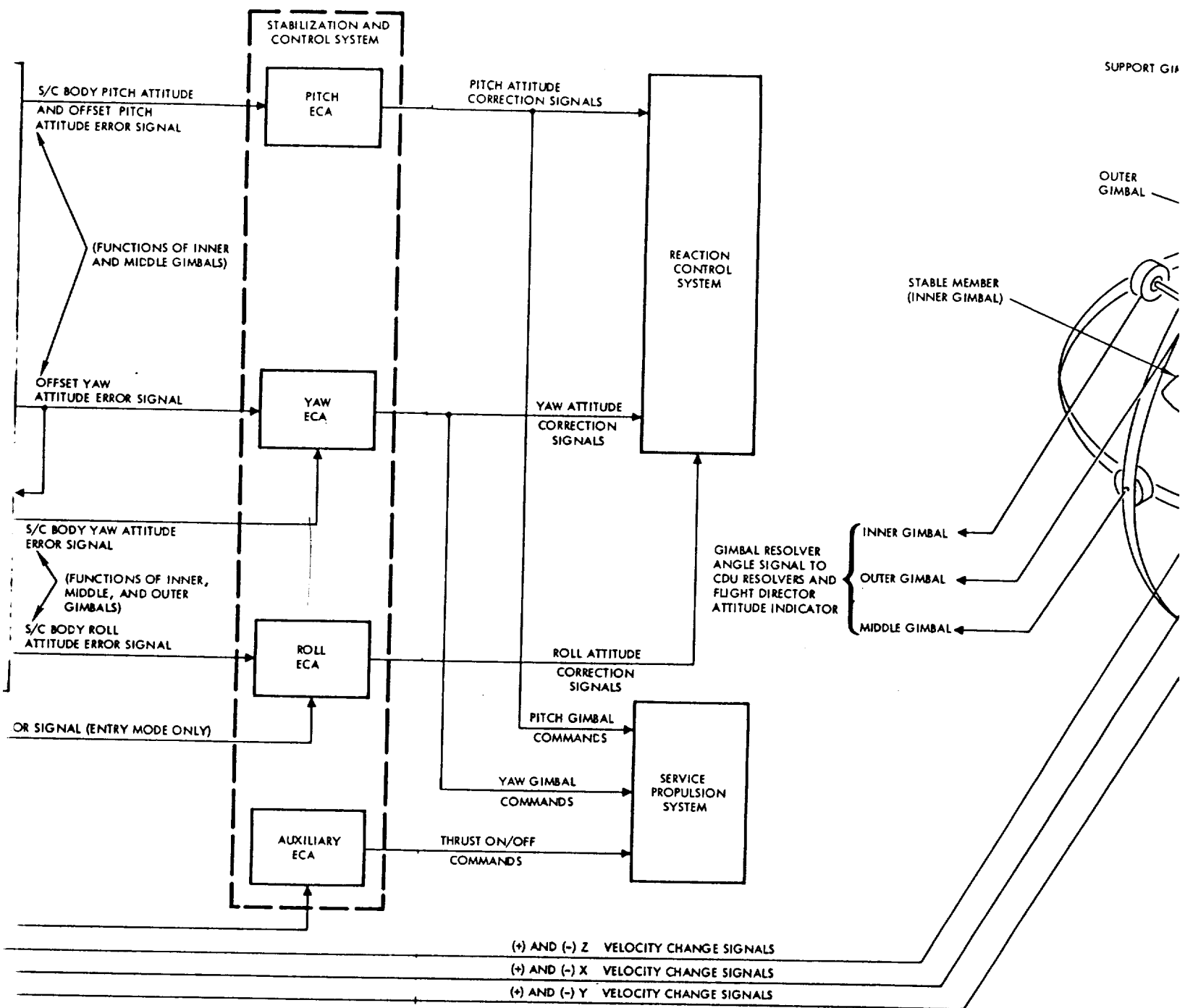




**SOLDOUT FRAME**

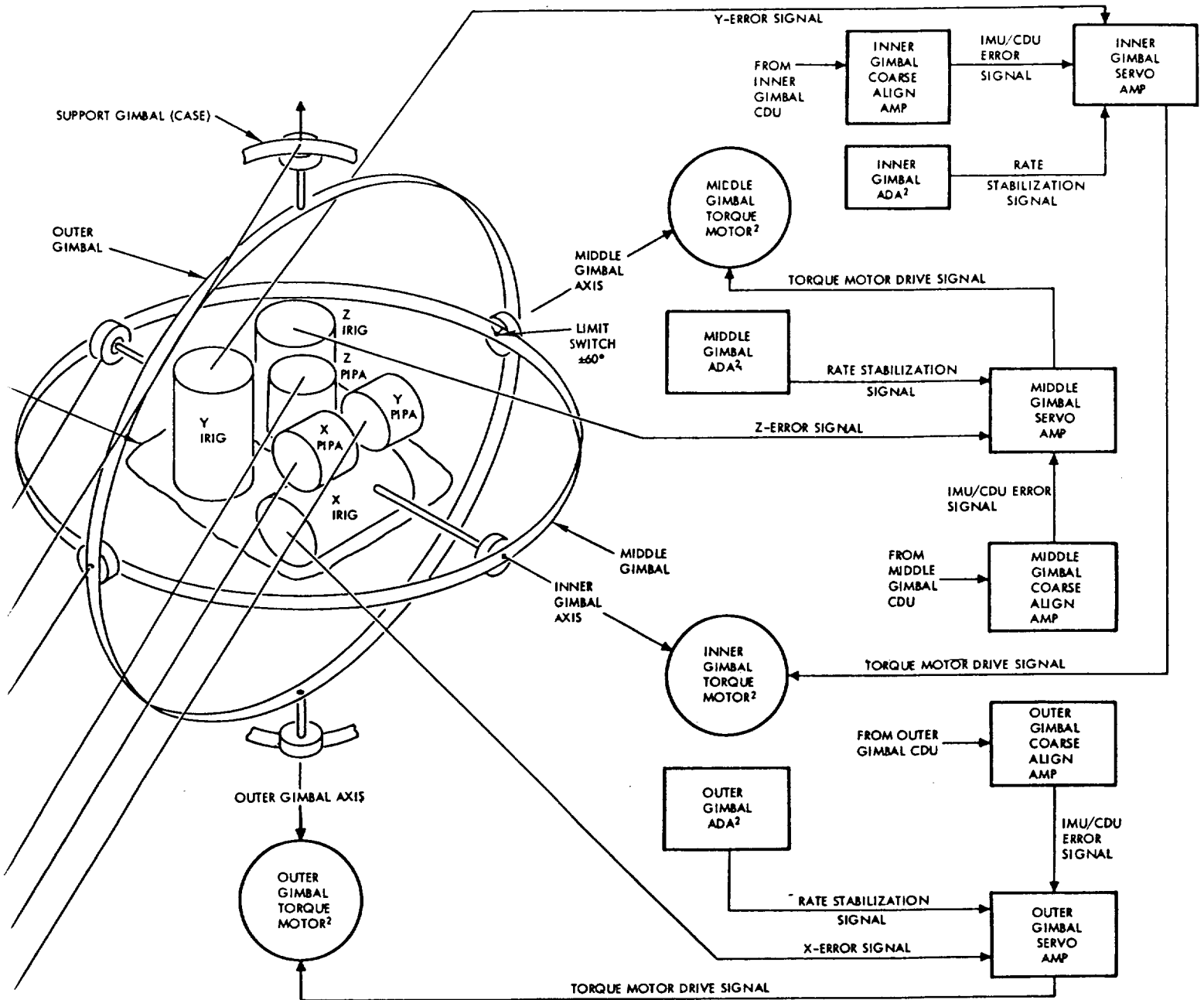
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Figure 2.2-2. G&N System Functional Block Diagram

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Mission \_\_\_\_\_ Basic Date 12 Nov 1966 Change Date \_\_\_\_\_ Page 2.2-5/2.2-6

**WOLDOUT FRAME**



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The optics provide accurate star and landmark angular measurements. Sightings are accomplished by the navigator using the SXT and SCT. The optics are positioned by drive motors commanded by the optics hand controller or manually using a universal tool, as desired. The shaft axes are parallel. Trunnion axes may be operated in parallel or offset, as desired. The SCT is a unity power instrument providing an approximate 60-degree field of view. It is used to make landmark sightings and to acquire and center stars or landmarks prior to SXT use. The SXT provides 28-power magnification with a 1.8-degree field of view. The SXT has two lines of sight, enabling it to measure the included angle between two objects. This requires two lines of sight which enable the two viewed objects to be superimposed. For a star-landmark sighting, the landmark line of sight is centered along the SXT shaft axis. The star image is moved toward the landmark by rotating the shaft and trunnion axes until the two viewed objects are superimposed. The shaft and trunnion angles are repeated by the optic CDUs. When the navigator is satisfied with image positions, he issues a mark command to the AGC. The AGC reads the optics CDU angles, IMU CDU angles, and time, and computes the position of the spacecraft. The AGC bases the computation on stored star and landmark data which may also be used by the AGC to request specific stars or landmarks for navigational sightings. Two or more sightings, on two or more different stars, must be taken to perform a complete position determination.

2.2.2.1 Operational Modes.

The G&N system is operated in six basic operational modes. Selection of any one mode is accomplished manually by the flight crew or automatically by the AGC. The basic modes are as follows:

- Monitor (initiated by SCS mode selection)
- Zero encode
- Coarse align
- Fine align
- Attitude control
- Entry

The system configuration necessary to operate in any of the modes is established by relay switching.

The monitor mode is used at launch, ascent, and during orbit until CSM/S-IVB separation, to provide flight path data for crew displays. The coarse align, fine align, and zero encode modes are used to align the IMU after standby periods or to acquire a new stable platform orientation. The attitude control mode provides for spacecraft attitude control and navigation computations to measure position and velocity. The entry mode provides control of the spacecraft lift vector during entry phase.

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The ISS and CSS will be operated in on-standby cycles to conserve electrical power. During standby operation, the ISS maintains IMU temperature, and the CSS maintains AGC timing functions. The OSS is shut off when not in use. Since standby operation time varies for each of the subsystems, standby is not considered as basic mode.

2.2.2.1.1 Monitor Mode.

During prelaunch operations, the G&N system is aligned to the desired launch reference attitude and gyro compasses to maintain this attitude. Approximately 3 minutes prior to launch, the gyro compassing is stopped and the system becomes inertially referenced. Upon lift-off the AGC begins monitoring the flight path angles by driving the Inertial Coupling Display Units (ICDUs) through programmed attitude changes. The ICDU angles are compared with the IMU gimbal angles to produce flight path error signals which are displayed by the FDAI error needles. Total spacecraft attitude, with respect to the IMU orientation, is displayed by the FDAI ball. (Prelaunch FDAI readings are 164.76-degree roll, 58.30-degree pitch, and 9.69-degree yaw, with respect to the navigation axis symbol. Display at orbit insertion is 0-degree roll, 310.5-degree pitch, and 0-degree yaw, assuming a 180-degree roll has been performed and launch pad 37 is used.) During boost prior to launch escape tower (LET) jettison, the AGC displays the following:

REGISTER 1 - Inertial flight path angle; inertial velocity with respect to local horizontal in degrees.

REGISTER 2 - Inertial velocity in ft per sec.

REGISTER 3 - Altitude above launch pad in nautical miles (NMs).

Upon receipt of LET jettison signals the displays change to the following:

REGISTER 1 - Predicted Gs for free-fall and entry at 60-degree bank angle.

REGISTER 2 - Altitude of perigee above the mean equatorial radius in NMs.

REGISTER 3 - Time of free-fall to 300,000 ft above mean equatorial radius in minutes and seconds.

This displayed data provides the flight crew with sufficient information to make abort or continue decisions; however, if time is not critical, the decision is made by the flight crew and MSFN jointly.

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2.2.2.1.2 Zero Encode Mode.

The zero encode mode enables correction of the CDU data stored in AGC. This mode is used to ensure that the reference angles contained in the CDU registers of the AGC correspond with the actual CDU angles. This is accomplished by driving the CDUs to zero, then clearing the AGC CDU registers. This starts the AGC CDU registers at zero and enables the registers to maintain correct CDU angles by counting pulses from the CDU digital encoders.

2.2.2.1.3 Coarse Align Mode.

The coarse align mode enables stable platform alignment to within approximately 2 degrees of a desired platform orientation. Prerequisite information to accomplish coarse alignment consists of the desired platform orientation and present spacecraft attitude.

The desired platform orientation angles are computed by an alignment program executed by the AGC. The navigator determines the spacecraft attitude immediately prior to coarse alignment by making two or more sightings on stars or landmarks. Upon completion of the sightings, the AGC reads the optic angles and computes the gimbal angles necessary to attain the desired platform orientation. The AGC generates drive signals to position the CDU resolvers to the required gimbal angles. The IMU-CDU resolver error signals, generated by repositioning the CDUs, are applied to the gimbal torque servo amps which drive the gimbal torque motors to position the platform to the desired orientation.

The stable platform orientation will normally be such that the X-axis lies along the spacecraft thrust vector during all powered phases, except ascent, and along the spacecraft stability axis during entry.

2.2.2.1.4 Fine Align Mode

The fine align mode completes stable platform orientation to the required degree of accuracy. The navigator makes two or more star sightings, using on-board data and the optics to acquire the desired stars. Upon receipt of the optic angles the AGC computes the IMU angles necessary to complete the alignment. In the fine align mode, the IMU angles are repeated by the inertial CDUs which are monitored by the AGC to determine the actual IMU orientation. The AGC generates torquing signals to cancel any error between the actual IMU orientation and the desired orientation. These torquing pulses are applied to the IRIG torquing coils. The IRIGs in conjunction with the stabilization loops, reposition the stable platform until the desired orientation is attained. Upon completion of fine alignment, the IMU/CDU resolver signals and the stabilization loop signals are at null.

The system configuration required for fine align mode also applies IMU resolver signals to the SCS as apparent attitude error signals. To prevent these signals from appearing as actual spacecraft attitude errors, the SCS must be operated in an SCS mode which rejects G&N derived signals.

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2.2.2.1.5 Attitude Control Mode.

The attitude control mode provides spacecraft attitude change sensing, generates error signals for spacecraft attitude control, velocity change signals for updating AGC velocity information, and signals for timing SPS engine thrust termination commands.

During spacecraft attitude control, the IMU gimbal resolvers sense any displacement of the spacecraft with respect to the stable platform orientation and produce corresponding error signals. The error signals are applied directly to the SCS-FDAI ball for error display and to the inertial CDU resolvers. The IMU-CDU error signals are displayed on the IMU control panel, resolved into spacecraft axes, and applied to the SCS. If the error signals indicate an attitude error larger than the selected deadband, appropriate RCS engines are fired and the desired spacecraft attitude is restored.

For delta V maneuvers, the G&N system provides attitude control, velocity change sensing, and total velocity change control by generating thrust termination commands. Prior to thrusting, the IMU is aligned so that the stable platform X-axis is parallel to the thrust vector. The AGC determines time-to-ignition and total velocity change desired, and performs mode verification routines. At ignition time the AGC flashes the DSKY displays to the crew for initiation of ignition (manual DSKY entry is required). During thrusting, the CDU applies attitude error signals to the SCS. Roll error signals are applied to the RCS engines; however, pitch and yaw error signals are applied to the SPS engine gimbals rather than RCS engines. This ensures alignment of the thrust vector through the spacecraft center-of-gravity and along the correct trajectory. The PIPAs on the stable platform sense the velocity changes and apply proportional output signals to the AGC. The AGC computes and updates spacecraft velocity, and counts down a preset counter with the PIPA signals. When the counter reaches zero, a thrust termination signal is generated and applied through the SCS electronics to the SPS engine.

2.2.2.1.6 Entry.

The entry mode provides for generation of attitude error and steering signals, sensing of deceleration, and computation of velocity changes during the entry phase of the mission. The steering signals provide for control of the spacecraft lift vector through the SCS, to inhibit excessive G-loadings and heat buildup, and to control the flight path to enable landing at a pre-selected site. Attitude error signals are applied to the FDAI attitude error needles.

Entry configuration is similar to attitude control with the exceptions that the roll response time is reduced, one step of axis resolution is not needed, and the AGC will produce steering signals to the SCS by driving the roll CDU. From initiation of entry mode until 0.05G switching, roll, pitch,

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and yaw error signals provide attitude control. Upon 0.05G switching, the pitch and yaw error signals provide display only. Prior to entry, the IMU X-axis is aligned along the spacecraft entry velocity vector. This alignment eliminates the need for navigation base-to-spacecraft body axis resolution. Deceleration is sensed primarily by the IMU X-axis PIPA, although changes in lift vector orientation cause some lateral movement which is sensed by the Y and/or Z PIPAs. The outer gimbal, or roll, 1X resolver is connected to the 16X resolver in the ROLL CDU, giving a 16:1 increase in attitude error signal and reducing the response time of the roll channel. The AGC will produce steering signals by executing a programmed lift vector down entry (to ensure capture), 180-degree roll to lift vector up, then generate further steering signals with respect to G forces, heat buildup, and range needed. These steering signals are routed to the roll CDU where an IMU-CDU resolver error is generated and routed to the SCS for FDAI display and/or RCS engine control. The entry may be performed manually with the pilot flying to the steering signals as displayed on the FDAI, or automatically with the AGC steering signals routed to the roll RCS engines for spacecraft control.

2.2.3 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

2.2.3.1 Inertial Subsystem.

The function of the inertial subsystem is to provide a space-stabilized inertial reference from which velocity changes and attitude changes can be sensed. It is composed of the inertial measurement unit (IMU), the navigation base (NB), parts of the power and servo assembly (PSA), parts of the control and display panels, and three coupling display units (CDUs).

2.2.3.1.1 Navigation Base.

The navigation base (NB) is the rigid, supporting structure which mounts the IMU and optical instruments. The NB is manufactured and installed to close tolerances to provide accurate alignment of the equipment mounted on it. It also provides shock mounting for the IMU and optics.

2.2.3.1.2 Inertial Measurement Unit.

The inertial measurement unit (IMU) is the main unit of the inertial subsystem. It is a three-degree-of-freedom stabilized platform assembly, containing three inertial reference integrating gyros (IRIGs), three pulsed integrating pendulous accelerometers (PIPAs), and three angular differentiating accelerometers (ADAs). The stable member itself is machined from a solid block of beryllium with holes bored for mounting the PIPAs, IRIGs, and one of the three ADAs. Three gimbal and six intergimbal assemblies, which house torque motors and resolvers, are also part of the IMU assembly, together with preamplifiers and gimbal-mounted electronics. Figure 2.1-2 shows how the IRIGs and the PIPAs are mounted relative to each other on the stable member (or inner gimbal). The three gimbal axes, about which each of the gimbals rotate, are also shown.

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The stable platform attitude is maintained by the IRIGs, ADAs, stabilization loop electronics, and gimbal torque motors. Any displacement of the stable platform or gimbal angles is sensed by the IRIGs and ADAs, which generate error signals. IRIG error signals are resolved and amplified at the IMU and applied to stabilization loop electronics. ADA-produced error signals are summed with the IRIG error signals. The resultant signal is conditioned and applied to the gimbal torque motors, which restore the desired attitude.

The stable platform provides a space-referenced mount for three PIPAs, which sense velocity changes. The PIPAs are mounted orthogonally to sense the velocity changes along all three axes. Any translational force experienced by the spacecraft causes an acceleration or deceleration which is sensed by one or more PIPAs. Each PIPA generates an output signal proportional to the magnitude and direction of velocity change. This signal, in the form of a pulse train, is applied to the AGC. The AGC will use the signal to update the velocity information and also generate signals to torque each PIPA back to null.

The temperature of the IRIGs and PIPAs is maintained within required limits during both standby and operating modes of the IMU. The IMU temperature control system contains circuits to supply normal proportional temperature control with the capability of backup or emergency control in case of a proportional malfunction. The proportional temperature control circuit is the primary means of maintaining the IRIG and PIPA temperature and provides the most accurate control. This type of control is available when either the proportional or auto-override mode is selected with the IMU TEMP MODE selector switch. The purpose of the auto-override mode is to provide automatic switching from that mode to emergency control if there is a malfunction in the proportional control circuit. If a malfunction occurs in the proportional mode, the switching to emergency control must be performed manually. In the proportional mode, the temperature is controlled by the proportional temperature control bridge and is maintained at  $135 \pm 0.5^\circ\text{F}$ . While in the emergency mode, it is controlled by the mercury thermostat and is held within  $\pm 5^\circ\text{F}$ .

The backup temperature control and indicator circuit is intended for use in the event the proportional control fails. The control sensing elements for this system are three PIPA indicating sensors (connected in series) and six IRIG sensing elements (connected in series) in two separate bridges. This system can maintain the temperature to within  $\pm 1^\circ\text{F}$ . In this mode of operation, an alarm indication is not available to the astronaut because of modifications to the temperature alarm amplifier circuit.

#### 2.2.3.1.3 Coupling and Display Units.

There are five CDUs mounted below the IMU control panel at the lower equipment bay. Three CDUs function as part of the ISS, while the two remaining CDUs function with the OSS. The optic CDUs (OCDUs) are described in paragraph 2.2.3.2. The three inertial CDUs (ICDUs) are identical and may be interchanged. Display dials on the front panel of each provide a 6-digit readout. Positioning of the ICDUs is accomplished by the AGC. Each ICDU contains a 1/4-speed, 1/2-speed, 1-speed, and 16-speed resolver, the functions of which depend upon the ISS mode of operation. The angular movements of the resolvers are converted into digital signals by a digital encoder, processed by encoder electronics, and routed to AGC registers which maintain current ICDU angles for use as desired. The AGC

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commands CDU movements by applying digital drive commands to digital-to-analog converters. The drive signals are converted from digital to analog and applied to CDU motor drive amplifiers which position the CDUs. The 1-speed and 16-speed resolvers function as receivers of signals produced by 1-speed and 16-speed resolvers mounted on the IMU. The 1/2-speed resolvers are used to zero the CDUs and the 1/4-speed resolvers are not used. The resolvers provide input signals to selector circuits which provide motor drive signals or spacecraft attitude error signals, depending upon ISS mode of operation. The IMU outer gimbal 1-speed resolver signals are applied to the roll CDU 16-speed resolver to increase roll control rates during entry.

2.2.3.1.4 Power and Servo Assembly.

The power and servo assembly (PSA), located just below the display and control panel in the lower equipment bay, serves as a central mounting point for most of the G&N electronic units such as power supplies and amplifiers. It also contains the backup electronics used to supply timing pulses to the IMU in case of an AGC timing malfunction. It consists of 10 removable trays mounted adjacent to each other and connected to a junction box. The PSA trays utilize three wiring harnesses to provide electrical connection: one for module-to-module connection, another for module-to-junction box connection, and a third for module connection to a 38-pin female test plug on the front of the PSA tray.

2.2.3.2 Optical Subsystem.

The optical subsystem is used for taking precise optical sightings on celestial bodies and for taking fixes on landmarks. These sightings are used for aligning the IMU and for determining the position of the spacecraft. The system includes the navigational base, two of the five CDUs, parts of the power and servo assembly, controls and displays, and the optics, which include the scanning telescope (SCT) and the sextant (SXT).

2.2.3.2.1 Optics.

The optics consist of the SCT and the SXT mounted in two protruding tubular sections of the optical base assembly. The SCT and SXT shaft axes are aligned parallel to each other and afford a common line-of-sight (LOS) to selected targets. The trunnion axes may be parallel or the SCT axis may be offset depending upon mode of operation.

The sextant is a highly accurate optical instrument capable of measuring the included angle between two targets. Angular sightings of two targets are made through a fixed beam splitter and a movable mirror located in the sextant head. The sextant lens provides 1.8-degree true field of view with 28X magnification. The movable mirror is capable of sighting a target to 57 degrees LOS from the shaft axis. The mechanical accuracy of the trunnion axis is twice that of the LOS requirement due to mirror reflection which doubles any angular displacement in trunnion axis.

The scanning telescope is similar to a theodolite in its ability to accurately measure elevation and azimuth angles of a single target using an established reference. The lenses provide 60-degree true field of view at 1X magnification. The telescope allowable LOS errors are 1 minute of arc rms in elevation with maximum repeatability of 15 arc/seconds and approximately 40 arc/seconds in shaft axis.

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2.2.3.2.2 Coupling Display Units.

The function of the OCDUs is to position and repeat angles of the SCT and SXT shaft and trunnion axes. The OCDUs are similar to the ICDUs, but may not be interchanged due to internal mechanical differences allowing higher OCDU rates. Each OCDU has a 6-digit display readout and can be positioned automatically by AGC command. CDU angles are converted to a digital signal by a digital encoder, processed by encoder electronics, and routed to an AGC register. AGC positioning commands are applied to a digital-to-analog converter, converted to a representative analog signal, and applied to a motor drive amplifier in the SXT. Resolvers in the SXT function as transmitters to CDU resolvers which receive the position signals and apply the commanded angles to the CDU motor drive amplifiers to position the CDU motor.

Trunnion CDU 1/4-speed and 16-speed resolvers function as receivers and provide drive signals to the trunnion CDU motor. The SXT trunnion resolvers which drive the CDU resolvers are 1-speed and 64-speed respectively, providing a 1:4 SXT trunnion to CDU trunnion ratio. Visual readouts on the trunnion display dials are thus four times the trunnion angle and two times the star line-of-sight angle from zero position. The 1/2-speed resolver, in conjunction with the cosecant amplifier, provides a variable gain computing resolver which is used in the RESOLVED mode of operation. The 1-speed resolver is not used in the trunnion CDU.

Shaft CDU 1/2-speed and 16-speed resolvers function as receivers and produce drive signals to the shaft CDU motor. SXT resolvers used as transmitters are also 1/2-speed and 16-speed resolvers, affording a 1:1 ratio; thus, the display dials provide direct readouts of the shaft angles. The 1-speed resolver resolves polar coordinates into rectangular coordinates for the RESOLVED mode of operation. The 1/4-speed resolver is not used in the shaft CDU.

2.2.3.2.3 Operational Modes.

Optics positioning is accomplished automatically by the AGC or manually by the crew. Overall mode control is established by crew selection of the ZERO OPTICS, MANUAL, or COMPUTER modes on the OPTICS panel.

ZERO OPTICS mode enables automatic drive of the SXT shaft and trunnion motors to zero. This is accomplished by applying the SXT resolver output signals to the input of the SXT motor drive amplifiers. The drive signals are applied to the CDU and SCT resolvers which follow the SXT shaft and trunnion axes to zero. After 60 seconds, the AGC optics position registers are cleared. This mode may be selected by AGC program or manually.

MANUAL mode enables positioning control of the optics by manual manipulation of the optics hand controller. The hand controller is mechanized such that, right-left movement generates shaft commands, and up-down movement generates trunnion commands. Hand controller drive rates are selected by the position of the CONTROLLER SPEED switch.

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Positions HI, MED, and LO control the amplitude of the drive signal to the hand controller. Hand controller drive signals are applied to the SXT shaft and trunnion drive amplifiers through the CONTROLLER MODE switch for selection of DIRECT or RESOLVED mode. In DIRECT mode, the image motion is presented in a polar coordinate reference frame; in RESOLVED mode, the image motion is presented in a rectangular coordinate reference frame.

In DIRECT mode, shaft commands move the image in a circular path around the center of the field of view. Trunnion commands drive the image in a straight line across the center of the field of view. The angular orientation of the trunnion commanded straight line movement is a function of the shaft angle; therefore, direction of image movement with respect to the direction of hand controller movement is also a function of shaft angle. The rate of image movement, for shaft commands, is a function of trunnion angle, wherein increasing trunnion angles result in increasing image movement rates.

In RESOLVED mode, shaft commands move the image left-right in a straight line. Trunnion commands move the image up-down in a straight line. Image movement is in the same direction as hand controller movement and the rate of movement is constant for varying angles.

In COMPUTER mode, the AGC positions the optics to a star or landmark determined by AGC programming. This mode is performed by an AGC routine which is called up automatically by various alignment programs. The target star or landmark may be defined by AGC programming or by the crew. If the target star or landmark is not selected by AGC programming, the crew makes a DSKY entry defining either the latitude, longitude, and altitude for a landmark or the star code for a star. The AGC determines the spacecraft attitude by monitoring the ICDUs, and computes the angles necessary to drive the optics to the desired target. (If the angles necessary to acquire the target are beyond the capabilities of the optics, the AGC flashes the DSKY displays.) When the necessary angles are computed, the AGC displays the desired shaft and trunnion angles on the DSKY and initiates OCDU drive to these angles. When the AGC has completed driving the CDUs, the crew checks the DSKY-displayed angles against the 6-digit CDU displays and the SCT counters. The crew then locates and identifies the target in the SCT, enables manual control, and completes the sighting. The AGC can also perform zero optics functions, if desired, by the AGC program.

The SCT trunnion may be operated in three alternate modes, with respect to the SXT trunnion, as desired. The SLAVE TELESCOPE switch enables crew selection of STAR LOS, LANDMARK LOS 0°, or OFFSET 25°. The STAR LOS position is normally used. In this position, the SCT trunnion is slaved to the SXT trunnion. The LANDMARK LOS 0° position, applies a fixed voltage to the SCT trunnion position loop causing it to null at zero. This holds center of the SCT 60° field of view parallel to the

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SXT landmark line of sight. The OFFSET 25° position applies a fixed voltage to the SCT trunnion position loop, causing it to null at 25 degrees off-center. This holds the SCT field of view so that the SXT landmark line of sight remains visible while sweeping the SCT shaft through 360 degrees of rotation, providing an approximate 110-degree total field of view.

2.2.3.3      Computer Subsystem.

The computer subsystem (CSS) consists of the Apollo guidance computer (AGC) and two display and keyboard panels (DSKYs). The AGC and one DSKY are located at the lower equipment bay. The other DSKY is located on the main display console. The AGC mounts one switch on the front panel which applies partial or full power to the computer to enable standby or full operation of the CSS. All other AGC controls and displays are located on the DSKYs. The keyboards on the DSKYs are similar; however, the displays on the DSKY in the lower equipment bay are more extensive.

2.2.3.3.1    Apollo Guidance Computer.

The Apollo guidance computer (AGC) is a digital computer using a two-part rope core memory. (See figure 2.2-3.) The AGC processes various data to provide control and computation functions. Input data is received from the crew, ISS, OSS, MSFN, and other spacecraft systems. This data is processed by various programs to provide outputs to the crew, ISS, OSS, MSFN, and other spacecraft systems in the form of commands and displays. The control functions performed by the AGC consist of the following:

- Align the IMU stable platform.
- Position the optics for navigation sightings.
- Command reaction control system engine firings to maintain specific attitude.
- Request initiation and command termination of service propulsion engine firings.
- Provide synchronization pulses to the central timing equipment.
- Command telemetry transmission to MSFN.
- Command ISS moding.
- Command OSS moding.

The reference data used to generate controls may be acquired externally or generated within the AGC. Initiation of the controls may be accomplished by the crew using the DSKYs, by MSFN via telemetry, or by an AGC program.

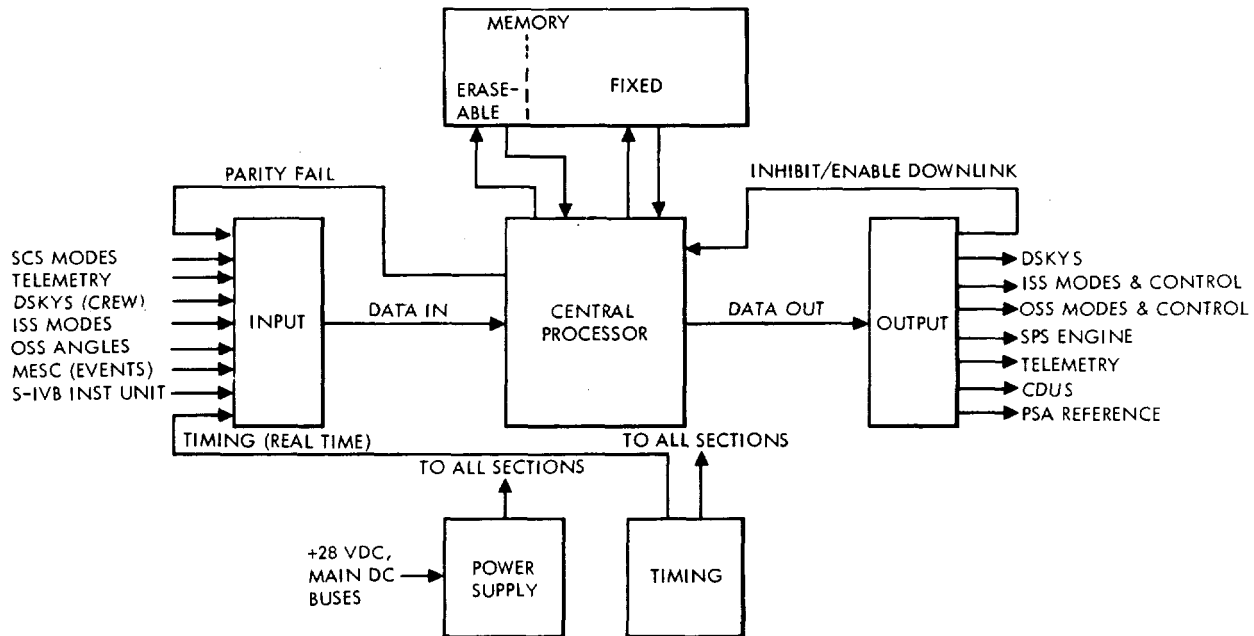
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Figure 2.2-3. AGC Functional Block Diagram

Computations are performed to generate the proper control commands, maintain navigation parameters, and complete various other operations under program control. AGC programs are stored in memory. The memory contains two sections, erasable and non-erasable. The erasable section provides storage for transient data. Readout is destructive; thus, if the data is to be retained, it must be written back into memory. Otherwise, the location is cleared for further use as desired. Non-erasable memory contains programs, routines, constants, star and landmark coordinates, and other pertinent data. Readout is non-destructive; thus, the data contained in this section is not lost and cannot be altered. AGC programs are performed by controlling the flow of data within the six basic sections listed as follows:

- Power supply
- Input
- Output

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- Central processor
- Memory
- Timing

Power Supply. The power supply consists of two parts. Input to the power supply is +28 vdc from the spacecraft main d-c bus. The two sections provide +13 vdc and +3 vdc. The +13-vdc output provides power to the DSKYs and, in conjunction with the +3-vdc power, to the logic circuits. The +3-vdc supply provides power to the timing section as well as to the logic circuits. During standby mode of operation, the +3-vdc section only is operated; thus, power consumption is reduced by approximately 100 watts.

Input. The input section consists of four registers which enable inter-communication between the AGC and the other G&N subsystems, the stabilization and control system, the mission sequencer, the S-IVB guidance, and MSFN. The utilization of the registers is such that each bit position in each register is assigned a specific task. For example, bit positions 1, 2, 3, 4, and 5 of input register 0 are assigned to receiving the five bit code generated when a DSKY key is pressed. Data received from the various sources are conditioned by the input registers such that, when it is transferred into the logic circuits, the signal levels and timing are correct. The data received by the four input registers are as follows:

Input 0 Register	Receives 5-bit code from the DSKYs, block uplink signal from the UPTTEL switch, control signals from the SCS mode control panel, and mark commands from the MARK pushbutton. Also monitors the signal from the telemetry bit rate detecting circuits.
Input 1 Register	This register is formed by the Scaler A register of the timing section which maintains real time during standby operation, and provides update information to the real time counters when full operation is resumed.
Input 2 Register	Receives 200, 400, 800, and 1600 pps signals from the Scaler A section of the timing section forming an extension of the real time counters for use by other spacecraft systems which require timing of this order. Also receives discrete event signals from the S-IVB instrument unit, CM/SM separation signals from the master events sequence controller, failure signals from the ISS, mode signals from the SCS, and parity fail signals.

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Input 3 Register	Receives ISS mode signals from the ISS mode relays and mode signals from the OSS, monitors the position of the TRANSFER switch, and provides a logic OR gate for 33 DSKY relays.
------------------	--

Output. The output section consists of four registers which enable the AGC to communicate with the flight crew, ISS, OSS, and other spacecraft systems. The utilization of the registers is similar to that used for the input section (i. e., each bit position, or group of bit positions is assigned a specific task). The tasks assigned to the various registers and bit positions are as follows:

Output 0 Register	Provides the transmission link from the AGC to the DSKYs by control of 14 banks of relays which provide display of data and routing of control signals to the ISS, OSS, and SCS.
-------------------	--

Output 1 Register	Receives internal AGC alarm signals and causes alarm indicators on the DSKYs to illuminate. Receives KEY RLSE request from an AGC program and causes the KEY RLSE indicator to illuminate and flash until the DSKY is released. Receives AGC signal indicating improper DSKY operation and causes the CHECK FAIL indicator to illuminate. Receives SPS engine firing signal from an AGC program, causing the DSKY to flash a request for crew initiation of engine firing. Receives SPS engine off command from an AGC program, removing the engine on signal. Also provides signal to reset the error interrupt trap circuits, identifies the type of word being transmitted by downlink telemetry, and inhibits further loading of telemetry words when the telemetry word rate exceeds 50 words per second.
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Output 2 Register	Controls application of 3200 pps control pulses to the ISS and OSS.
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Output 3 Register	Serves as a spare register for the central processor when needed.
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Output 4 Register	Contains the next word to be transmitted by downlink telemetry.
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**Central Processor.** The central processor contains the logic circuits and registers which perform the programs. Programs are executed by performing instructions in a sequence controlled by the sequence generator. There are two basic types of instructions. The first is the machine instruction which consists of regular, involuntary, and miscellaneous instructions. Regular instructions are contained within the program and are part of the data words being processed. Involuntary instructions are performed as interrupts to the program and are generated externally to the AGC. Miscellaneous instructions are used in the computer test only. The second basic type of instruction is the interpretive instructions and are a programmer convenience which are converted under program control to machine instructions. The execution of the instructions is a function of the sequence generator. The sequence generator combines basic timing pulses with the instruction portion of a data word and performs the program in the necessary sequence. Regular machine instructions are processed by the sequence generator initiation of the instruction. The instruction will perform one or more subinstruction, the last of which will be a subinstruction to proceed to the next instruction. Involuntary instructions are initiated by an interrupt from an external source, after which the instruction is performed in the same manner as a regular instruction. After completion of the involuntary instruction, a "resume" command is executed and the sequence generator returns to the program which was interrupted. The central processor performs the data manipulation by adding, subtracting, shifting, etc., within a group of central registers, adder, and parity block. The functions of the registers are as follows:

A Register	Accumulator. Stores the results of arithmetic processing.
LP Register	Stores the least significant portions of the product of a multiply instruction.
B Register	Used to complement (by reading the reset side of the register), as temporary storage, and as a buffer.
Z Register	Program counter. Contains address of next instruction. Incremented by one as each instruction is performed. (Instructions are usually stored in memory sequentially.)
Q Register	If transfer control occurs the contents of Z are read into and stored in Q until interrupt is completed. Enables interrupted program to restart at the proper instruction. Also used in division. Stores remainder in complemented form.
Input 0, 1, 2, 3	Refer to Input section description.
Output 0, 1, 2, 3	Refer to Output section description.

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G Register	Provides access to and from memory. Shifting, under program control, takes place in this register. Parity bit is removed and restored in this register.
S Register	Contains address of word to be called from memory. If word is in fixed memory, this selects word in conjunction with BANK register.
BANK Register	Selects bank in fixed memory. Operates in conjunction with S register.
SQ Register	Stores 4 bit order code of instruction word.
X, Y, U Registers	These registers form the adder. Two numbers to be added are placed in X and Y. The result is stored in U.
Parity Circuit	The parity circuit checks the parity of words coming from memory to be odd. If parity is not correct, this circuit generates a parity alarm. Words being returned to memory are given the proper parity bit by this circuit.

Data flow within the central processor is initiated by an instruction. A data word is brought from memory to the G register. The G register provides temporary storage of the word until it is needed. If the word came from erasable memory, it will usually be written back into the same location during the same memory cycle time it is transferred to the G register. (This is not necessary for words from fixed memory, as readout is not destructive.) The word is then routed to the parity circuits for a parity check and to have the parity bit removed. The sequence generator next controls the transfer of the data word to the other registers for processing. If the result of the processing is to be written back into memory, the word is transferred back into the G register, the parity bit is added, and the word transferred back to memory. If the processing consists of arithmetic functions, it is performed in the adder (X, Y, and U registers). The AGC has the capability to add only; therefore, subtraction, multiplication, and division are performed by complementing and/or shifting, then adding.

Memory. The AGC memory consists of two sections. The largest section is the fixed memory. This is a rope core type having a capability of 24,576 sixteen bit words. Readout is non-destructive and the data contained cannot be changed. All permanent, pre-determined data, such as programs, tables, constants, star and landmark angles, etc., are contained in this section. Addressing the data contained in the fixed

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section is accomplished by the S and BANK registers. A smaller erasable section provides temporary storage for transient data. Erasable memory is a coincident-current core array with a capacity of 1024 sixteen bit words. Readout is destructive, so if data is to be retained, it is necessary to write the data back into the location when it is read out. Addressing the data contained in erasable memory is done by the S register.

Timing. The timing section generates the synchronization pulses for AGC operations and timing pulses for other spacecraft systems. The timing section is divided into the following functional groups:

Clock Divider	This group contains the basic clock oscillator which has a 2.048 mc frequency divided to time various AGC logic functions and certain outputs, clock the time pulse generator, and drive Scaler A.
Scalers A and B	<p>Scaler A contains 17 binary dividers producing signals of various frequencies used within the AGC logic, as reference to the PSA, and to drive Scaler B. Scaler B contains 16 binary dividers producing timing signals to the Input 1 register for maintaining real time when the AGC is in standby.</p> <p>Scalers A and B are used in conjunction with the Input 0 register, TIME 1, and TIME 2 counters to provide real time.</p>
Time Pulse Generator	Produces 12 basic timing pulses which define action times. These pulses are used to control internal sequencing of data processing.
Memory Pulse Generator	This group provides timing pulses to fixed and erasable memory to synchronize read and write operations.
Start-Stop Logic	The start-stop logic generates three commands. A monitor stop command inhibits the time pulse generator and stops AGC data word flow. A monitor start command generates the third signal which is a clear command to the sequence generator.

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2.2.3.3.2 Display and Keyboard.

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The DSKYs facilitate intercommunication between the flight crew and the AGC. (See figure 2.2-4.) The DSKYs operate in parallel, with the main display console DSKY providing AGC display and control while the crew are in their couches. The two condition lights provided at the main display console DSKY are COMPUTER FAIL, which is a gross AGC failure indicator, and KEY RLSE, which is a request to the crew to release the DSKY circuits to internal AGC program use. The main display console DSKY also has an UPTTEL switch which enables the AGC to accept or block telemetered data from MSFN. The DSKY at the lower equipment bay contains the remainder of the condition lights: PROG ALM, RUPT LOCK, PARITY FAIL, TC TRAP, TM FAIL, COUNTER FAIL, SCALER FAIL, CHECK FAIL and KEY RLSE. All the condition lights except KEY RLSE are failure indicators. (KEY RLSE is a request for the crew to release the DSKY circuits to internal AGC program use.) This DSKY also has a TEST ALARM push-button which is wired to the alarm relays to provide a check of the warning lights. The electroluminescent displays are identical on each DSKY and always display identical data. The intensity of these displays is controlled by the BRIGHTNESS thumbwheels.

The exchange of data between the flight crew and the AGC is usually initiated by crew action; however, it can also be initiated by internal computer programs. The exchanged information is processed by the DSKY program. This program allows the following four different modes of operation:

- Display of Internal Data—Both a one-shot display and a periodically updating display (called monitor) are provided.
- Loading External Data—As each numerical character is entered, it is displayed in the appropriate display panel location.
- Program Calling and Control—The DSKY is used to initiate a class of routines which are concerned with neither loading nor display. Certain routines required instructions from the operator to determine whether to stop or continue at a given point.
- Changing Major Mode—The initiation of large scale mission phases can be commanded by the operator.

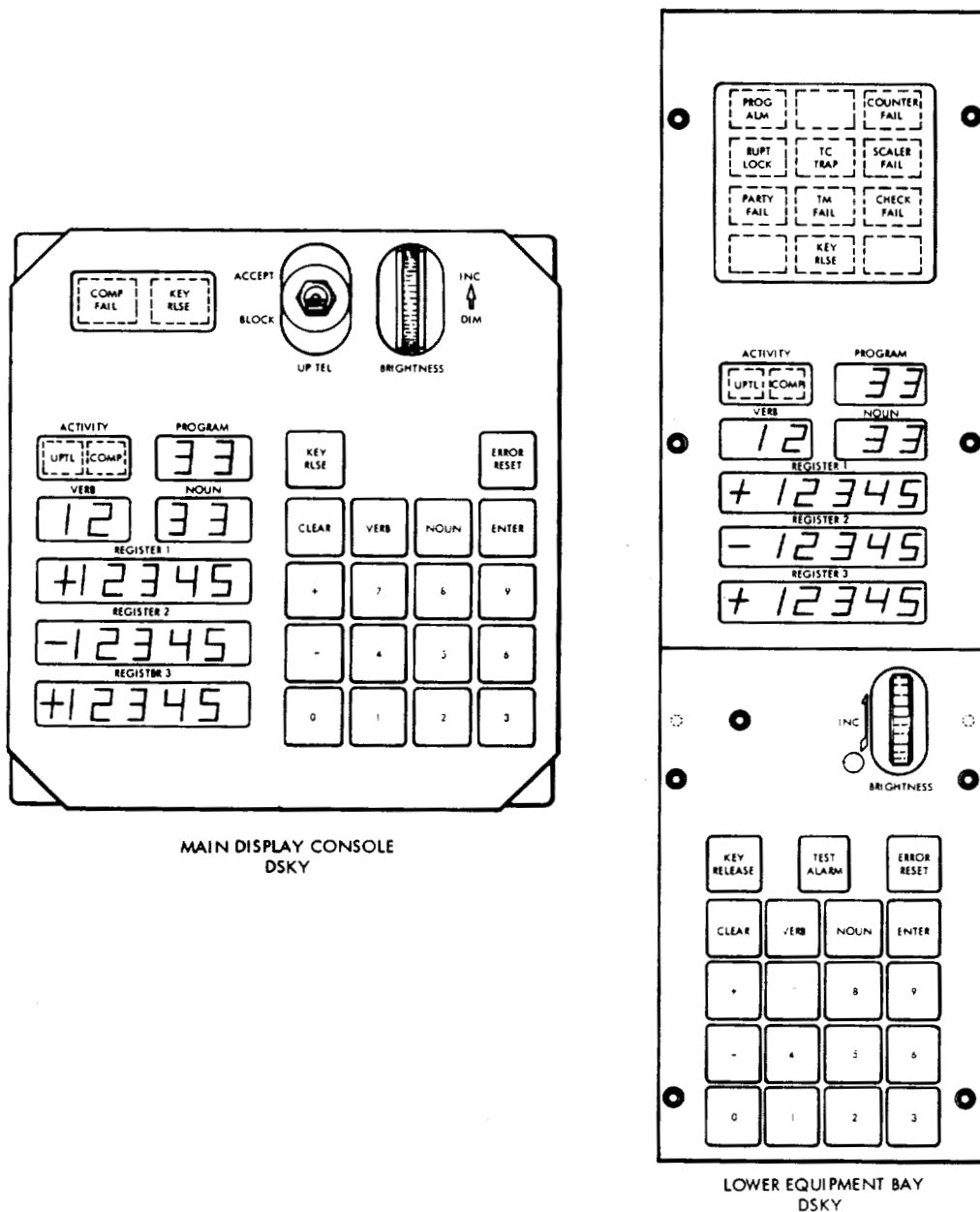
The data involved in both loading and display can be presented in either octal or decimal form as the operator indicates. If decimal form is chosen, the appropriate scale factors are supplied by the program. Decimal entries are indicated by entering a sign (+, -).

Keyboard Operation. The basic language of communication between the operator and the AGC is a pair of words known as verb and noun. Verb and noun codes are defined in figures 2.2-5 and 2.2-6, respectively. Each

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Figure 2.2-4. Display and Keyboard Panels

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of these is represented by a two-character octal number. The verb code indicates what action is to be taken (operation); the noun code indicates to what action is applied (operand). Typical verbs are those for displaying and loading. Nouns usually refer to a group of erasable registers within the computer memory. The PROGRAM, VERB, and NOUN displays provide two digit numbers which are coded octal numbers describing the action being performed. The REGISTER 1, 2, and 3 displays provide display of the contents of registers or memory locations. These displays are numbers which are read as decimal numbers if a sign (+, -) is present and octal numbers if no sign is used. The REGISTER displays operate under program control unless the contents of a specific register or memory location is desired. The crew may request display of the contents of a specific register or memory location by commanding the display from the keyboard. The only other displays are the ACTIVITY lights which indicate whether the computer is computing or accepting telemetry from MSFN.

The keyboard provides 18 keys which, when pressed, generate a five bit signal representative of the key pressed. The +, -, and 0-9 keys are used for numerical entries, while the CLEAR, ENTER, VERB, NOUN, KEY RELEASE, and ERROR RESET keys provide instructions. The TEST ALARM key is wired to the alarm relays and provides a check of the warning indicator lights with the exception of SCALER FAIL. The main display console DSKY UPTTEL switch enables or inhibits the acceptance of telemetry from MSFN. The function of each of the keys is as follows:

0-9	Enter numerical data, addresses, and action codes.
VERB	Commands AGC to accept the next two numbers as verb code data. Verb display is blanked until numbers are entered.
NOUN	Commands AGC to accept the next two numbers as noun code data. Noun display is blanked until numbers are entered.
ENTER	Instructs AGC to accept keyed-in data as completed and initiate operation specified by data word.
CLEAR	Enters all zeros in data register being loaded. Each successive pressing of this key clears the next higher register.
KEY RLSE	Release the DSKY circuits and displays for use by the AGC program being executed.
ERROR RESET	Momentarily resets AGC failure lights.

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(+) and (-)	Denotes sign of data to follow. Denotes that following data is decimal.
TEST ALARM	Sets relays to illuminate LEB DSKY condition lights (except SCALER FAIL) to ensure proper operation. (LEB DSKY only.)
UPTTEL	Sets AGC input registers to accept or inhibit telemetered data from MSFN. (MDC DSKY only.)
BRIGHTNESS	Provides control of intensity of electro-luminescent displays.

The lower equipment bay DSKY provides nine condition lights of which eight are failure indicators and the remaining light a request for action. The function of each is as follows:

PROG ALM	The AGC program being executed has detected an error.
COUNTER FAIL	Detected failure in input timing pulses. Either interrupt or circuitry failed. Interrupt failure is denoted by RUPT LOCK failure indicator illumination.
RUPT LOCK	Interrupt failed to occur or was not completed within specified time.
TC TRAP	Transfer control instruction has not occurred, or has occurred but was not completed within a specified time.
SCALER FAIL	Failure detected in AGC timing section.
PARITY FAIL	Parity failure detected in data read from memory.
TM FAIL	Telemetry word rate to MSFN either too high or too low. Telemetry word rate from MSFN too high or incorrect transmission of data.
CHECK FAIL	Attempted illegal DSKY operation. Normally operator error.
KEY RLSE	Flashes to indicate AGC program in operation requires DSKY circuitry to continue.

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The standard procedure for the execution of keyboard operations consists of a sequence of seven key depressions:

VERB    V<sub>2</sub>    V<sub>1</sub>    NOUN    N<sub>2</sub>    N<sub>1</sub>    ENTER

Pressing the VERB key blanks the two verb lights on the DSKY and clears the verb code register in the AGC. The next two numerical inputs are interpreted as the verb code, in octal form. Each of these characters is displayed by the verb lights as it is inserted. The NOUN key operates similarly with the DSKY noun lights and AGC noun code register. Pressing the ENTER key initiates the program indicated by the verb-noun combination displayed on the DSKY. Thus, it is not necessary to follow a standard procedure in keying verb-noun codes into the DSKY. It can be done in reverse order, if desired, or a previously inserted verb or noun can be used without rekeying it. No action is taken by the AGC in initiating the verb-noun-defined program until the ENTER key is actuated. If an error is noticed in either the verb code or noun code prior to actuation of the ENTER key, it can be corrected simply by pressing the corresponding VERB or NOUN key and inserting the proper code. The ENTER key should not be actuated until it has been verified that the correct verb and noun codes are displayed.

If the selected verb-noun combination requires data to be loaded by the operator, the VERB and NOUN lights start flashing on and off (about once per second) after the ENTER key is pressed. Data is loaded in five-character words and, as it is keyed in, it is displayed character-by-character in one of the five-position data display registers, REGISTER 1, REGISTER 2, or REGISTER 3. Numerical data is assumed to be octal unless the five-character data word is preceded by a plus or minus sign, in which case it is considered to be decimal. Decimal data must be loaded in full five-numeral character words (no zeros may be left out); octal data may be loaded with high order zeros left out. If decimal is used for any component of a multicomponent load verb, it must be used for all components of that verb. In other words, no mixing of octal and decimal data is permitted for different components of the same load verb. The ENTER key must be pressed after each data word. This tells the program that the numerical word being keyed in is complete. The on-off flashing of the VERB-NOUN lights terminates after the last ENTER key actuation of a loading sequence.

The CLEAR key is used to remove errors in loading data as it is displayed in REGISTER 1, REGISTER 2, or REGISTER 3. It does nothing to the PROGRAM, NOUN, or VERB lights. (The NOUN lights are blanked by the NOUN key, the VERB lights by the VERB key.) For single-component load verbs or "machine address to be specified" nouns, the CLEAR key depression performs the clearing function on the particular register being loaded, provided that the CLEAR key is depressed before the ENTER key. Once the ENTER key is depressed, the CLEAR key does nothing. The only way to correct an error after the data is entered for

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a single-component load verb is to begin the load verb again. For two- or three-component load verbs, there is a CLEAR backing-up feature. The first depression of the CLEAR key clears whichever register is being loaded. (The CLEAR key may be pressed after any character, but before its entry.) Consecutive CLEAR key actuations clear the data display register above the current one until REGISTER 1 is cleared. Any attempt to back up (clear) beyond REGISTER 1 is simply ignored. The CLEAR backing up function operates only on data pertinent to the load verb which initiated the loading sequence. For example, if the initiating load verb were a "write second component into" type only, no backing up action would be possible.

The numerical keys, the CLEAR key, and the sign keys are rejected if depressed after completion (final entry) of a data display or data load verb. At such time, only the VERB, NOUN, ENTER, ERROR RESET, or KEY RELEASE inputs are accepted. Thus, the data keys are accepted only after the control keys have instructed the program to accept them. Similarly, the + and - keys are accepted only before the first numerical character of REGISTER 1, REGISTER 2, or REGISTER 3 is keyed in and at no other time. The 8 or 9 key is accepted only while loading a data word which is preceded by a + or - sign.

The DSKY can also be used by internal computer programs for subroutines. However, any operator keyboard action (except ERROR RESET) inhibits DSKY use by internal routines. The operator retains control of the DSKY until he wishes to release it. Thus, he is assured that the data he wishes to observe will not be replaced by internally initiated data displays. In general, it is recommended that the operator release the DSKY for internal use when he has temporarily finished with it. This is done by pressing the KEY RELEASE key.

Verb-Noun Formats. The verb-noun codes are defined in figures 2.2-5 and 2.2-6. A noun code may refer to a device, a group of computer registers, or a group of counter registers, or it may simply serve to convey information without referring to any particular computer register. The noun is made up of 1, 2, or 3 components, each component being entered separately as requested by the verb code. As each component is keyed, it is displayed on the display panel with component 1 displayed in REGISTER 1, component 2 in REGISTER 2, and component 3 in REGISTER 3. There are two classes of nouns: normal and mixed. Normal nouns (codes 01 through 54) are those whose component members refer to computer registers which have consecutive addresses and use the same scale factor when converted to decimal. Mixed nouns (codes 55 through 77) are those whose component members refer to nonconsecutive addresses or whose component members require different scale factors when converted to decimal, or both.

A verb code indicates what action is to be taken. It also determines which component member of the noun group is to be acted upon. For

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example, there are five different load verbs. Verb 21 is required for loading the first component of the selected noun; verb 22 loads the second component; verb 23 loads the third component; verb 24 loads the first and second component; and verb 25 loads all three components. A similar component format is used in the display and monitor verbs. There are two general classes of verbs: standard and extended. The standard verbs (codes 01 through 37) deal mainly with loading, displaying, and monitoring data. The extended verbs (codes 40 through 77) are principally concerned with calling up internal programs whose function is system testing and operation.

Whenever data is to be loaded by the operator, the VERB and NOUN lights flash, the appropriate data display register is blanked, and the internal computer storage register is cleared in anticipation of data loading. As each numerical character is keyed in, it is displayed in the proper display register. Each data display register can handle only five numerical characters at a time (not including sign). If an attempt is made to key in more than five numerical characters at a time, the sixth and subsequent characters are simply rejected but they do appear in the display register.

The + and - keys are accepted prior to inserting the first numerical character of REGISTER 1, REGISTER 2, or REGISTER 3; if keyed in at any other time, the signs are rejected. If the 8 or 9 key is actuated at any time other than while loading a data word preceded by a + or - sign, it is rejected and the CHECK FAIL light goes on.

The normal use of the flash is with a load verb. However, there are two special cases when the flash is used with verbs other than load verbs.

- Machine Address to be Specified—There is a class of nouns available to allow any machine address to be used; these are called "machine address to be specified" nouns. When the "ENTER", which causes the verb-noun combination to be executed, senses a noun of this type the flash is immediately turned on. The verb code is left unchanged. The operator should load the complete machine address of interest (five-character octal). This is displayed in REGISTER 3 as it is keyed in. If an error is made in loading the address, the CLEAR key may be used to remove it. Pressing the ENTER key causes execution of the verb to continue.
- Change Major Mode—To change major mode, the sequence is VERB 37 ENTER. This causes the noun display register to be blanked and the verb code to be flashed. The two-character octal major mode code should then be loaded. For verification purposes, it is displayed as it is loaded in the noun display register. The entry causes the flash to be turned off, a request for the new major mode to be entered, and a new major mode code to be displayed in the PROGRAM display register.

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Verb Code	Description	Remarks
<b>NOTE</b>		
Verb codes 01 through 37 denote standard verbs.		
01	Display 1st component of	Performs octal display of data on REGISTER 1.
02	Display 2nd component of	Performs octal display of data on REGISTER 1.
03	Display 3rd component of	Performs octal display of data on REGISTER 1.
04	Display 1st and 2nd components of	Performs octal display of data on REGISTER 1 and REGISTER 2.
05	Display 1st, 2nd, and 3rd component of	Performs octal display of data on REGISTER 1, REGISTER 2, AND REGISTER 3.
06	Display all component(s) of	Performs decimal display of data on appropriate registers. The scale factors, types of scale factor routines, and component information are stored within the machine for each noun which it is required to display in decimal.
07	DP decimal display	Performs a double precision decimal display of data on REGISTER 1 and REGISTER 2. It does no scale factoring. It merely performs a 10-character, fractional decimal conversion of two consecutive, erasable registers, using REGISTER 1 and REGISTER 2. The sign is placed in the REGISTER 1 sign position with the REGISTER 2 sign position remaining blank. It cannot be used with mixed nouns. Its intended use is primarily with "machine address to be specified" nouns.
10	Enter request to waitlist (Used only during ground checkout.)	Enters request to "waitlist routine" for any machine address with delay involved. This verb assumes that the desired number of 10-millisecond units of delay has been loaded into the low order bits of the prio/delay register (noun 26). This verb is used with the "machine address to be specified" noun. The complete address of the desired location is then keyed in. (Refer to "Machine address to be specified" in paragraph on Verb/Noun Formats.)
11	Monitor 1st component	Performs octal display of updated data every 1/2 second on REGISTER 1.
12	Monitor 2nd component of	Performs octal display of updated data every 1/2 second on REGISTER 1.
13	Monitor 3rd component of	Performs octal display of updated data every 1/2 second on REGISTER 1.
14	Monitor 1st and 2nd component of	Performs octal display of updated data every 1/2 second on REGISTER 1 and REGISTER 2.
15	Monitor 1st, 2nd, and 3rd component of	Performs octal display of updated data every 1/2 second on REGISTER 1, REGISTER 2, and REGISTER 3.
16	Monitor all components(s) of	Performs decimal display of updated data every 1/2 second on appropriate registers.
17	Monitor DP decimal	Performs double precision display of decimal data on REGISTER 1 and REGISTER 2. No scale factoring is performed. Provides 10-character, fractional decimal conversion of two consecutive erasable registers. The sign is placed in the sign-bit position of REGISTER 1. REGISTER 2 sign bit is blank.
20	Enter request to executive (Used only during ground checkout.)	Enters request to executive routine for any machine address with priority involved. This verb assumes that the desired priority has been loaded into bits 10-14 of the prio/delay register (noun 26). This verb is used with the noun, "machine address to be specified". The complete address of the desired location is then keyed in. (Refer to "Machine address to be specified" in paragraph on Verb/Noun Formats.)
21	Write 1st component into	Performs data loading. Octal quantities are unsigned. Decimal quantities are preceded by + or - sign. Data is displayed on REGISTER 1.

Figure 2.2-5. Verb List (Sheet 1 of 3)

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Verb Code	Description	Remarks
22	Write 2nd component into	Performs data loading. Octal quantities are unsigned. Decimal quantities are preceded by + or - sign. Data is displayed on REGISTER 2.
23	Write 3rd component into	Performs data loading. Octal quantities are unsigned. Decimal quantities are preceded by + or - sign. Data is displayed on REGISTER 3.
24	Write 1st and 2nd component into	Performs data loading. Octal quantities are unsigned. Decimal quantities are preceded by + or - sign. Data is displayed on REGISTER 1 and REGISTER 2.
25	Write 1st, 2nd, and 3rd component into	Performs data loading. Octal quantities are unsigned. Decimal quantities are preceded by + or - sign. Data is displayed on REGISTER 1, REGISTER 2, and REGISTER 3.
26	(Spare)	
27	(Spare)	
30	(Spare)	
31	Bank Display	This verb is included to permit displaying the contents of fixed memory in any bank. Its intended use is for checking program ropes and the BANK position of program ropes.
32	(Spare)	
33	Proceed without data	Informs routine requesting data to be loaded that the operator chooses not to load fresh data, but wishes the routine to continue as best it can with old data. Final decision for what action should be taken is left to requesting routine.
34	Terminate	Informs routine requesting data to be loaded that the operator chooses not to load fresh data and wishes the routine to terminate. Final decision for what action should be taken is left to requesting routine. If monitor is on, it is turned off.
35	(Spare)	
36	Fresh start	Initializes the program control software and the keyboard and display system program.
37	Change major mode to	Change to new major mode. (Refer to "Change major mode" in paragraph on Verb-Noun Formats.)
<b>NOTE</b>		
Verb codes 40 through 77 denote extended verbs.		
40	Zero	Must be used with noun 20 (ICDU) or noun 55 (OCDU) only. Sets the CDU registers to zero.
41	Coarse align IMU	Must be used with noun 20 (ICDU) or noun 55 (OCDU) only.
42	Fine align IMU	Calls up programs that perform the indicated G&N system procedures.
43	Lock IMU	Calls up programs that perform the indicated G&N system procedures.
44	Set IMU to ATTITUDE CONTROL	Calls up programs that perform the indicated G&N system procedures.
45	Set IMU ENTRY	Calls up programs that perform the indicated G&N system procedures.
46	Return IMU to coarse align	Calls up programs that perform the indicated G&N system procedures.

Figure 2.2-5. Verb List (Sheet 2 of 3)

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Verb Code	Description	Remarks
47	(Spare)	
50	Please perform	This verb is used only by internal routines that wish the operator to perform a certain task. It should never be keyed in by the operator. It is usually used with noun 25, "checklist." The coded number for the checklist item to be performed is displayed in REGISTER 1 by the requesting routine.
51	Please mark	This verb is used only by internal routines that request the operator to "mark". It should never be keyed in by the operator. It is usually used with noun 30, "star numbers". The numbers of the stars to be marked are displayed in REGISTER 1; REGISTER 2, and REGISTER 3 by the requesting routine. The operator should indicate completion of each valid mark by pressing the MARK button. He should never press ENTER with verb 51.
52	Mark reject	Rejects "mark" and returns to verb 51. Must be entered within 20 seconds of pressing MARK button.
53	Free	Calls up programs that perform the indicated G&N system procedures. Used only with noun 20 (ICDU) or noun 55 (OCDU).
54	Pulse torque gyros	Calls up programs that perform the indicated G&N system procedures.
55	Align time	
56	Perform BANK sum	
57	System test (Used only during ground checkout.)	
60	Prepare for standby	
61	Recover from standby	
62	(Spare)	
63	(Spare)	
64	Calculate orbital parameters	
65	Calculate time of arrival at longitude	
66	Calculate latitude and longitude at specified time	
67	Calculate maximum declination and time of arrival	
70	(Spare)	
71	(Spare)	
72	(Spare)	
73	Return to Earth aim point update	
74	Orbit change aim point update	
75	Manual lift-off for flights	
76	R. V. T. update (state vector)	R. V. T. denotes position, velocity, and time.
77	(Spare)	

Figure 2.2-5. Verb List (Sheet 3 of 3)

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Noun Code	Description	Scale/Units	Noun Code	Description	Scale/Units
	<b>NOTE</b>  Noun codes 01 through 54 denote normal nouns.	<b>NOTE</b>  In Scale/Units column:  X = significant digit 0 = zero (always) B = blank.	22	New angles I: X-REGISTER 1 Y-REGISTER 2 Z-REGISTER 3	XXX. XX degrees XXX. XX degrees XXX. XX degrees
01	Specify machine address	XXXXX	23	Delta angles I: X-REGISTER 1 Y-REGISTER 2 Z-REGISTER 3	XXX. XX degrees XXX. XX degrees XXX. XX degrees
02	Specify machine address	XXXXX.	24	Delta time for AGC clock: REGISTER 1 REGISTER 2 REGISTER 3	00XXX. hours 000XX. minutes 0XX. XX. seconds
03	(Spare)		25	Checklist (Used only with verb 50, "Please perform".)	XXXXX.
04	(Spare)			Checklist code numbers (Appear in REGISTER 1.)	
05	Angular error	XXX. XX degrees	00001	SCS mode to G&N attitude control	
06	Pitch angle	XXX. XX degrees	00002	SCS mode to G&N Delta V	
	Heads up-down	±00001	00003	SCS mode to G&N entry	
07	Change of program or major mode (Used only with verb 50, "Please perform".)		00004	SCS mode to monitor	
10	(Spare)		00007	Manual attitude maneuver	
11	Engine on enable (Used only with verb 50, "Please perform".)		00011	Automatic optics positioning	
12	Delta V allowable	XXXXX. ft/sec	00012	Target data entry	
	Delta V tailoff	XXXXX. ft/sec	00013	Switch OSS to computer control	
13	Delta V measured (Vector magnitude.)	XXXXX. ft/sec	00014	Fine align check	
14	Delta V counter setting.	XXXXX. ft/sec	00015	Perform star acquisition	
15	Increment address (Used only during ground checkout.)	Octal only	00031	Engine on	
16	AGC clock time: REGISTER 1 REGISTER 2 REGISTER 3	00XXX. hours 000XX. minutes 0XX. XX seconds	00035	Prepare AGC for thrusting	
17	(Spare)		00036	Thrust terminate	
20	ICDUs: X-REGISTER 1 Y-REGISTER 2 Z-REGISTER 3	XXX. XX degrees XXX. XX degrees XXX. XX degrees	00041	C/M-S/M separation	
21	PIPA counters: X-REGISTER 1 Y-REGISTER 2 Z-REGISTER 3	XXXXX. pulses XXXXX. pulses XXXXX. pulses	26	Prio/delay (Used only during ground checkout.)	XXXXX.
			27	Self test ON-OFF switch	XXXXX.
			30	Star number	XXXXX.

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Figure 2.2-6. Noun List (Sheet 1 of 3)

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Noun Code	Description	Scale/Units	Noun Code	Description	Scale/Units
31	Failure register code		43	Perigee altitude REGISTER 1	XXXX.X nautical miles
	<b>NOTE</b>			Apogee altitude REGISTER 2	XXXX.X nautical miles
	Error codes are defined in paragraph 2.2.2.3.3.	Octal only		Free-fall time REGISTER 3	XXBXX. minutes, seconds
	Self-test diagnosis REGISTER 2	Octal only	44	Latitude REGISTER 1	XXX.XX degrees
	Self-test diagnosis REGISTER 3	Octal only		Longitude REGISTER 2	XXX.XX degrees
32	Decision time (Used only during ground checkout.)			Altitude (Above mean equatorial radius.) REGISTER 3	XXXX.X nautical miles
33	Ephemeris time (Used only during ground checkout.)		45	Perigee altitude REGISTER 1	XXXX.X degrees
34	Event time:			Apogee altitude REGISTER 2	XXXX.X degrees
	REGISTER 1	00XXX. hours		Delta velocity required REGISTER 3	XXXXX. ft/sec
	REGISTER 2	000XX. minutes	46	Time to event REGISTER 1	XXBXX. minutes, seconds
	REGISTER 3	0XX.XX seconds		Velocity to be gained REGISTER 2	XXXXX. ft/sec
35	Delta event time:			Perigee altitude REGISTER 3	XXXX.X nautical miles
	REGISTER 1	00XXX. hours	47	Flight path angle REGISTER 1	XXX.XX degrees
	REGISTER 2	000XX. minutes		Miss distance REGISTER 2	XXXX.X nautical miles
	REGISTER 3	0XX.XX seconds	50	Time to event REGISTER 1	XXBXX. minutes, seconds
36	Delta event time (Display only.)	XXBXX. minutes, seconds		Delta time of burn REGISTER 2	XXBXX. minutes, seconds
37	(Spare)		51	Time to event REGISTER 1	XXBXX. minutes, seconds
40	Gamma (Inertial flight path angle.) REGISTER 1	XXX.XX degrees		Velocity to be gained REGISTER 2	XXXXX. ft/sec
	Inertial velocity REGISTER 2	XXXXX. ft/sec		Measured velocity change along spacecraft X-axis REGISTER 3	XXXXX. ft/sec
	Altitude above launch pad REGISTER 3	XXXX.X nautical miles			
41	Maximum acceleration REGISTER 1	XXXX.X g's			
	Perigee altitude REGISTER 2	XXXX.X nautical miles			
	Free-fall time REGISTER 3	XXBXX. minutes, seconds			
42	Miss distance REGISTER 1	XXXX.X nautical miles			
	Perigee altitude REGISTER 2	XXXX.X nautical miles			
	Free-fall time REGISTER 3	XXBXX. minutes, seconds			

Figure 2.2-6. Noun List (Sheet 2 of 3)

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Noun Code	Description	Scale/Units	Noun Code	Description	Scale/Units
52	Time to event REGISTER 1	XXBXX. minutes, seconds	63	Latitude REGISTER 1	XX. XXX degrees
	Velocity to be gained REGISTER 2	XXXXX. ft/sec		Longitude/2 REGISTER 2	XX. XXX degrees
	Free-fall time REGISTER 3	XXBXX. minutes, seconds		Altitude REGISTER 3	XXX. XX nautical miles
53	Maximum acceleration REGISTER 1	XXXX. X g's	64	(Spare)	
	Free-fall time REGISTER 2	XXBXX. minutes seconds	65	Sampled time (Fetched in interrupt.) REGISTER 1 REGISTER 2 REGISTER 3	00XXX. hours 000XX. minutes 0XX. XX seconds
54	Commanded roll angle REGISTER 1	XXX. XX degrees	66	System test results (Used only during ground checkout.)	
	Present acceleration REGISTER 2	XXXX. X g's	67	Delta gyro angles: (Used only during ground checkout.)  X-IRIG REGISTER 1  Y-IRIG REGISTER 2  Z-IRIG REGISTER 3	XX. XXX degrees XX. XXX degrees XX. XXX degrees
	<b>NOTE</b>  Noun codes 55 through 77 denote mixed nouns.		70	Pitch trim REGISTER 1  Yaw trim REGISTER 2  Delta velocity tailoff REGISTER 3	XXX. XX degrees XXX. XX degrees XXXXX. ft/sec
55	OCDUs: X (Shaft angles) REGISTER 1  Y (Trunnion angles) REGISTER 2	XXX. XX degrees XX. XXX degrees	71	(Spare)	
56	Uncalled mark data: X (Shaft angles) REGISTER 1  Y (Trunnion angles) REGISTER 2	XXX. XX degrees XX. XXX degrees	72	Delta position (Used only during ground checkout.)	
57	New angles-OCDUs: X (Shaft angles) REGISTER 1  Y (Trunnion angles) REGISTER 2	XXX. XX degrees XX. XXX degrees	73	Delta velocity (Used only during ground checkout.)	
60	IMU mode status (Used only during ground checkout.)	Octal only	74	(Spare)	
61	Target: (Used only during ground checkout.)  Azimuth REGISTER 1  Elevation REGISTER 2	XXX. XX degrees XX. XXX degrees	75	Delta position magnitude REGISTER 1  Delta velocity magnitude REGISTER 2  Measurement angle deviation REGISTER 3	XXXX. X nautical miles XXXXX. ft/sec XXX. XX degrees
62	Delta velocity insertion REGISTER 1  Miss distance REGISTER 2  Free-fall time REGISTER 3	XXXXX. ft/sec XXXX. X nautical miles XXBXX. minutes, seconds	76	R-position (Used only during ground checkout.)	
			77	V-velocity (Used only during ground checkout.)	

Figure 2.2-6. Noun List (Sheet 3 of 3)

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The flash is turned off by any of the following events:

- Final entry of a load sequence
- Entry of verb "proceed without data" (33)
- Entry of verb "terminate" (34).

It is important to conclude every load verb by one of the aforementioned three, especially if the load was initiated by program action within the computer. If an internally initiated load is not concluded validly, the program that initiated it may never be recalled. The "proceed without data" verb is used to indicate that the operator is unable to, or does not wish to, supply the data requested, but wants the initiating program to continue as best it can with old data. The "terminate" verb is used to indicate that the operator chooses not to load the requested data and also wants to terminate the requesting routine.

2.2.3.3.3 Error Codes.

Error code numbers appear in REGISTER 1 with noun 31.

OSS Errors

00101	Optics mode control switched from ZERO OPTICS before end of 30 seconds.
00102	AGC unable to achieve desired optics mode.
00103	Function not valid for SC 012.
00104	No vacant area available for marks.
00105	Internal mark request while mark system is busy.
00106	Function not valid for SC 012.
00107	Mark reject while mark system is not in use.
00110	Mark reject with all requested marks accepted or no marks since initiating last mark reject.
00120	Too many marks.

ISS Errors

00201	Zero encode ended before end of 30 second wait.
00202	AGC unable to achieve desired ISS mode.
00203	No ISS mode indicated to AGC.
00204	ISS mode changed while TRANSFER switch is in COMPUTER position, but AGC did not command mode change.

Procedural Difficulties

00401	Desired gimbal angles will produce gimbal lock. (Middle gimbal angle greater than 60°.)
00402	Star out of field of view.
00403	Same as 00402.
00404	IMU orientation unknown.
00405	SCS mode monitor failure.

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00406 Navigation program busy.  
00407 Navigation program needed internally.  
00410 AGC update not allowed.

AGC Hardware Malfunctions

01101 Unused interrupt (RUPT 2) occurred  
01102 AGC self-test error.  
01103 Unused count, compare, and skip (CCS) branch executed.  
01104 C-relay failed during C-relay test.  
01105 Star search failure.  
01106 IMU orientation no good for entry.

List Overflows

01201 Executive overflow-no vacant areas.\*  
01202 Executive overflow-no core sets.\*  
01203 Waitlist overflow-too many tasks.\*  
01204 Same as 01203.\*  
01205 Master control overflow-too many jobs waiting.\*  
01206 DSKY waiting line overflow.\*  
01207 No vacant area for marks.\*  
01210 Something already waiting in IMU stall.\*

Interpreter Errors

01301 Arccos-arcsin input angle too large.\*  
01302 Square root called for with a negative argument.\*

Display Alarms

01401 VG increasing-loss of control.  
01402 Delta V too low-engine not on.

DSKY Program Errors

01501 Check fail alarm during internal use.\*

\*These alarms are "aborts" and define alarms which initiate a restart of the AGC program which was in progress when the alarm appeared.

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2.2.3.3.4 AGC Programs.

The following list of AGC programs defines the programs and routines applicable to SC-012. The AGC programs provide the major modes of G&N system operation. The routines consist of a specific sequence of operations which are performed by more than one program and/or other routine.

Program Number	Title	Contains Routines
00	AGC Idling	
01	Prelaunch Initialization	
02	Gyro Compassing	
03	Optical Azimuth Verification	
04	Inertial Reference	
05	G&N Startup	
06	G&N Power Down	
07	Systems Test (Limited in-flight use.)	
11	Pre-LET Jettison	
12	Post-LET Jettison	R 24, R 34
17	LET Abort	
22	Landmark Tracking	R 27, R 28
23	Star/Landmark Navigation Measurement	
24	Ground Track Determination	
27	AGC Update	
31	Orbit Change (Prethrust)	R 1, R 21, R 35
32	Return to Earth (Prethrust)	R 1, R 21, R 36
33	SPS Minimum Impulse (Prethrust)	R 1, R 21, R 31, R 33
41	Orbit Change	R 2, R 22, R 24, R 31, R 34, R 37

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Program Number	Title	Contains Routines
42	Return to Earth	R 2, R 22, R 24, R 31, R 34, R 37
43	SPS Minimum Impulse	R 2, R 31, R 34, R 37
51	IMU Orientation Determination	R 27, R 29
52	S-IVB/IMU Align	R 4, R 25, R 27, R 28, R 29, R 30
53	CSM/IMU Align	R 1, R 4, R 21, R 25, R 27, R 28, R 29, R 30
54	IMU Realignment	R 27, R 29, R 30
61	Maneuver To CM/SM Separation Attitude	R 1, R 21
62	CM/SM Separation And Pre-Entry Maneuver	R 3, R 21
63	Initialization	
64	Post 0.05G	
67	Final Phase	
71	First Abort Burn	R 24
Routine Number	Title	Contains Routines
1	Attitude Control Mode Check	R 22
2	Thrust Control Mode Check	R 1, R 21, R 22
3	Entry Control Mode Check	R 22
4	Fine Alignment	R 25, R 27, R 28, R 29, R 30
21	Attitude Maneuver	
22	SCS Discrete Monitor	
24	Delta V Monitor	R 38

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Routine Number	Title	Contains Routines
25	Coarse Alignment	R 38
27	Sighting Mark	
28	Auto Optics Positioning	
29	Star Data Test	
30	Gyro Torquing	
31	Backup Delta V Counter	
33	Prethrust SPS Minimum Impulse Data Load	
34	Orbit Parameter Display	
35	Prethrust Orbit Change Data Load	
36	Prethrust Return to Earth Data Load	
37	SPS Engine Ignition	
38	SPS Engine Thrust Fail	

2.2.4 PERFORMANCE AND DESIGN DATA.

(TBD)

2.2.5 OPERATIONAL LIMITATIONS AND RESTRICTIONS.

2.2.5.1 S/C Attitude.

The S/C should not be maneuvered to an attitude which will align the inner circle of either red area on the FDAI ball under the navigation axis marker. Failure to avoid this condition can result in IMU gimbal lock. Specifically, the following maneuvers should be avoided:

- Yaw maneuver greater than  $\pm 75$  degrees when roll angle is 0 degree or 180 degrees.
- Pitch maneuver greater than +42 degrees or -108 degrees when roll angle is  $\pm 90$  degrees.

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2.2.5.2 IMU Operation.

- The AGC must be ON before the IMU is placed in operation by engaging the IMU circuit breakers.
- The AGC must be ON or in STANDBY before the IMU is placed in standby mode.
- Allow 15 seconds for the stabilization loops to completely stabilize the platform after applying operating power, i.e., after engaging the IMU circuit breakers.
- The IMU must be in full operation for at least 1 hour before valid operation of the inertial components can be assumed.
- The inertial components will suffer a loss of calibration if the temperature falls below 120°F or exceeds 140°F. Damage will occur if the temperature falls below 40°F or exceeds 160°F.
- Do not operate the IMU such that the middle gimbal angle reaches or exceeds 70 degrees.

2.2.5.3 Optics Operation.

- Do not slew the SXT or SCT into the mechanical stops.
- Do not drive the 2X TRUNNION CDU in excess of 180 degrees as read on the CDU display dials. Insure that this display dial indicates less than 180 degrees before engaging the ZERO OPTICS mode of operation.

2.2.6 TELEMETRY MEASUREMENTS.

The following is a complete list of all G&N system telemetry data that is monitored by flight controllers and ground support personnel. The last column contains the name and type of S/C crew display. The display utilizes the same pickoff or signal source as telemetry, unless a separate measurement number is included in the display column.

An asterisk (\*) by the measurement number denotes information which is not available for recording or telemetry transmission during PCM low bit rate operation.

Measurement Number	Description	Sensor Range	Nominal Operating Range	Crew Display
CG 0001 V	Computer digital data 40 bits	+4/+132 vdc		None
CG 1101 V	-28 VDC supply	-30/0 vdc	-28 vdc	None

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Measurement Number	Description	Sensor Range	Nominal Operating Range	Crew Display
CG 1110 V	2.5 VDC TM bias	TBD	-28 vdc	None
CG 1503 X	IMU +28 vdc operate	Event		None
CG 1513 X	IMU +28 vdc standby	Event		None
CG 1523 X	AGC +28 vdc	Event		None
CG 1533 X	Optics +28 vdc	Event		None
CG 2110 V	IGA torque motor input	TBD		None
*CG 2112 V	IGA 1X res output sine in phase	TBD		None
*CG 2113 V	IGA 1X res output cos in phase	TBD		None
*CG 2117 V	IGA servo error in phase	0/0.5 vrms		None
CG 2140 V	MGA torque motor input	TBD		None
*CG 2142 V	MGA 1X res output sine in phase	TBD		None
CG 2143 V	MGA 1X res output cos in phase	TBD		None
*CG 2147 V	MGA servo error in phase	0/0.5 vrms		None
CG 2170 V	OGA torque motor input	TBD		None
*CG 2172 V	OGA 1X res output sine in phase	TBD		None
*CG 2173 V	OGA 1X res output cos in phase	TBD		None
*CG 2177 V	OGA servo error in phase	0/0.5 vrms		None

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Measurement Number	Description	Sensor Range	Nominal Operating Range	Crew Display
*CG 2206 V	IGA CDU 1X res error in phase	0/0.2 vrms		None
*CG 2236 V	MGA CDU 1X res error in phase	0/0.2 vrms		None
*CG 2266 V	OGA CDU 1X res error in phase	0/0.2 vrms		None
CG 2300 T	PIPA temp	TBD	+126.0°F/ +134.0°F	None
CG 2301 T	IRIG temp	TBD	+129.5°F/ +137.5°F	None
CG 2302 C	IMU heater current	0/+5 amps	0/+2 amps	None
CG 2303 C	IMU blower current	0/+5 amps	0/+1 amp	None
*CG 3102 V	SXT trun motor drive in phase	TBD		None
*CG 3112 V	SXT shaft motor drive in phase	TBD		None
*CG 3133 V	SCT trun motor drive	TBD		None
*CG 3141 V	Trun CDU 16X res error in phase	TBD		None
*CG 3200 V	Trun CDU motor drive in phase	TBD		None
*CG 3220 V	CDU motor drive RMS	TBD		None
*CG 4300 T	AGC temp monitor	TBD		None
CG 5000 X	PIPA fail	Event		ACCEL FAIL, G&N ACCEL FAIL C&W lights (2).
CG 5001 X	IMU fail	Event		IMU FAIL C&W lights (2).

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Measurement Number	Description	Sensor Range	Nominal Operating Range	Crew Display
CG 5002 X	CDU fail	Event		CDU FAIL C&W lights (2)
CG 5003 X	Gimbal lock warning	Event		GIMBAL LOCK, GMBL LOCK C&W lights (2).
CG 5005 X	Error detect	Event		PGNS, G&N ERROR C&W lights (2).
CG 5006 X	IMU temp light	Event		IMU TEMP C&W lights (2).
CG 5007 X	Zero encode light	Event		ZERO ENCODER, ZERO ENC. C&W lights (2).
CG 5008 X	IMU delay light	Event		IMU DELAY. C&W light.
CG 5020 X	AGC alarm 1 (Program)	Event		PROG ALM, COMP FAIL (DSKY lights).
CB 5021 X	AGC alarm 2 (AGC activity)	Event		COMP DSKY lights (2).
CG 5022 X	AGC alarm,3 (TM)	Event		TM FAIL, COMP FAIL. (DSKY lights).
CG 5023 X	AGC alarm 4 (prog ck fail)	Event		CHECK FAIL, COMP FAIL. (DSKY lights).
CG 5024 X	AGC alarm 5 (scaler fail)	Event		SCALER FAIL, COMP FAIL. (DSKY lights).
CG 5025 X	AGC alarm 6 (parity fail)	Event		PARITY FAIL, COMP FAIL. (DSKY lights).
CG 5026 X	AGC alarm 7 (counter fail)	Event		COUNTER FAIL, COMP FAIL. (DSKY lights).
CG 5027 X	AGC alarm 8 (key release)	Event		KEY RLSE (DSKY lights) (2).
CG 5028 X	AGC alarm 9 (rupt lock)	Event		RUPT LOCK, COMP FAIL. (DSKY lights).

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Measurement Number	Description	Sensor Range	Nominal Operating Range	Crew Display
CG 5029 X	AGC alarm 10 (TC trap)	Event		TC TRAP, COMP FAIL. (DSKY lights).
CG 5030 X	Computer power fail light	Event		AGC PWR FAIL (DSKY lights) (2).
*CG 6000 P	IMU pressure	TBD		None
*CG 6020 T	PSA temp 1 tray 3	TBD		None
*CG 6021 T	PSA temp 2 tray 2	TBD		None
*CG 6022 T	PSA temp 3 tray 4	TBD		None

G&N

2.2.7 G&N POWER CONSUMPTION.

The optics are only powered up when a star or landmark sighting is required. The subsystems power levels are as follows:

Description	Control	Power Reqmt's
IMU—operate standby	CB 59 and 58 CB 61 and 60	325.0 watts (dc) 61-7 watts (dc)
AGC—operate standby	CB 57 and 56 AGC Mode Switch	115.0 watts (dc) 15.0 watts (dc)
Optics—operate	CB 55 and 54	124.4 watts (dc) 14.4 watts (dc)
Controls and displays	CB 93 and 62 and Switch No. 7	
AGC only		10.0 watts (dc)
AGC and IMU		10-7 watts (dc)
Full G&N operation		18-7 watts (dc) 7-0 watts (dc)

Minimum power consumption is 76.7 watts (dc) when AGC and IMU are in the standby mode.

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2.2.8 INTERFACE SIGNALS.

The following list provides the signal, source, and description of the interface signals.

Signal Name	Source	Description
Stabilization and Control System (SCS) and G&N System Interface		
Engine on-off	AGC (Apollo guidance computer)	Provides pulse train that lasts as long as the engine is required to fire. The time at which the signal terminates takes into account electronic delays within the SCS and tail-off characteristics of the engines.
Discrete signal carrier	AGC	Provides continuous pulse train to the SCS to be switched back to the AGC.
G&N system attitude control (or SCS attitude control)	SCS	Provides power to an attitude control switch on the G&N system.
Minimum impulse enable	G&N system	Disables all three attitude channels simultaneously and supplies voltages to an attitude control switch on the G&N system.
Minimum impulse + and - pitch, yaw, and roll	SCS	Provides six signals to the G&N system for hand controller operation.
Minimum impulse pitch, yaw, and roll	G&N system	Provides the capability to initiate spacecraft attitude changes in the G&N system attitude control mode or the SCS attitude control mode. These changes will be initiated by discrete minimum impulses.
Pitch error body offset and body axis	G&N system	Provides pitch attitude error signal to the SCS.
Yaw error body offset axis	G&N system	Provides yaw attitude error signal to the SCS during G&N system entry mode.
Yaw error body axis	G&N system	Provides yaw attitude error signal to the SCS during normal G&N system operating modes.
Roll error body offset axis	G&N system	Provides roll attitude error signal to the SCS during G&N system entry mode.
Roll error body axis	G&N system	Provides roll attitude error signal to the SCS during normal G&N system operating modes.

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Signal Name	Source	Description
IMU 28V 800 cps (demodulator reference)	G&N system	Provides an 800 cps, synchronous, in-phase voltage from the G&N system.
IMU sin $A_{IG}$ 1X, IMU cos $A_{IG}$ 1X, IMU sin $A_{MG}$ 1X, IMU cos $A_{MG}$ 1X, IMU sin $A_{OG}$ 1X, and IMU cos $A_{OG}$ 1X	G&N system	Provides total attitude signals to the SCS.

G&N

Electrical Power System (EPS) and G&N System Interface

+28 vdc AGC bus A and bus B	EPS	Provides power to the AGC.
+28 vdc optics bus A and bus B	EPS	Provides power to the optics subsystem.
+28 vdc IMU bus A and bus B	EPS	Provides power to the IMU.
+28 vdc standby bus A and bus B	EPS	Provides IMU temperature control power.
115v 400 cps	EPS	Provides power for all G&N system 6-volt lamps

Communication and Instrumentation System and G&N System Interface

DLNK sync	AGC	Synchronizes data transferred from the AGC to the communications and instrumentation system.
DLNK end	AGC	Permits two AGC words to be transferred from the AGC to the communications and instrumentation system. Stops the AGC and the transmission of data from the AGC to the communications and instrumentation system.
DLNK start	AGC	Provides pulse signal that occurs at the beginning of every data transmission to the communications and instrumentation system. Sets flip-flop in AGC that enables 5-stage downlink counter.
DLNK data	AGC	Initiates by DLNK start, stopped by DLNK end, and consists of a 40 bit telemetry word (two AGC words and an 8 bit telemetry word order code).
ULNK 1	AGC	Transmitted to the uplink counter in the AGC. Adds one to uplink counter and shifts the counter one increment.

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Signal Name	Source	Description
ULNK 0	AGC	Transmitted to the uplink counter in the AGC. Shifts uplink counter one increment.

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SECTION 2

SUBSECTION 2.3

SCS

STABILIZATION AND CONTROL SYSTEM (SCS)

2.3.1 INTRODUCTION.

The stabilization and control system (SCS) provides a capability for controlling rotation, translation, and thrust vector forces with additional capability of rate stabilization.

The SCS is divided into three basic subsystems: attitude reference, attitude control, and thrust vector control. These subsystems contain the elements which provide for manual attitude control, automatic attitude control, and thrust vector control, plus manual backup provisions for all automatic functions.

The subsystem/control capability allows the free selection of several modes of operation which fall within the boundaries of three entirely different flight control profiles. These include coasting flight (earth orbital environment), powered flight (atmospheric - ascent, and earth orbital environment), and atmospheric flight (entry - unpowered).

Spacecraft displays provide a capability for monitoring S/C attitude, S/C rates, attitude errors, cautions, and warnings. Controls provide switch arrangements for commanding modes, commanding inputs to change operating status and to permit manual override to all automatic functions.

The SCS interfaces with the following S/C systems (See figure 2.3-1).

- Telecommunications System (T/C)

Provides clock reference frequency for measurement of changes in S/C velocity

Receives all down-link telemetry from SCS

Provides up-data position information via AGC or voice

- Electrical Power System (EPS)

Provides primary power for SCS operation

- Environmental Control System (ECS)

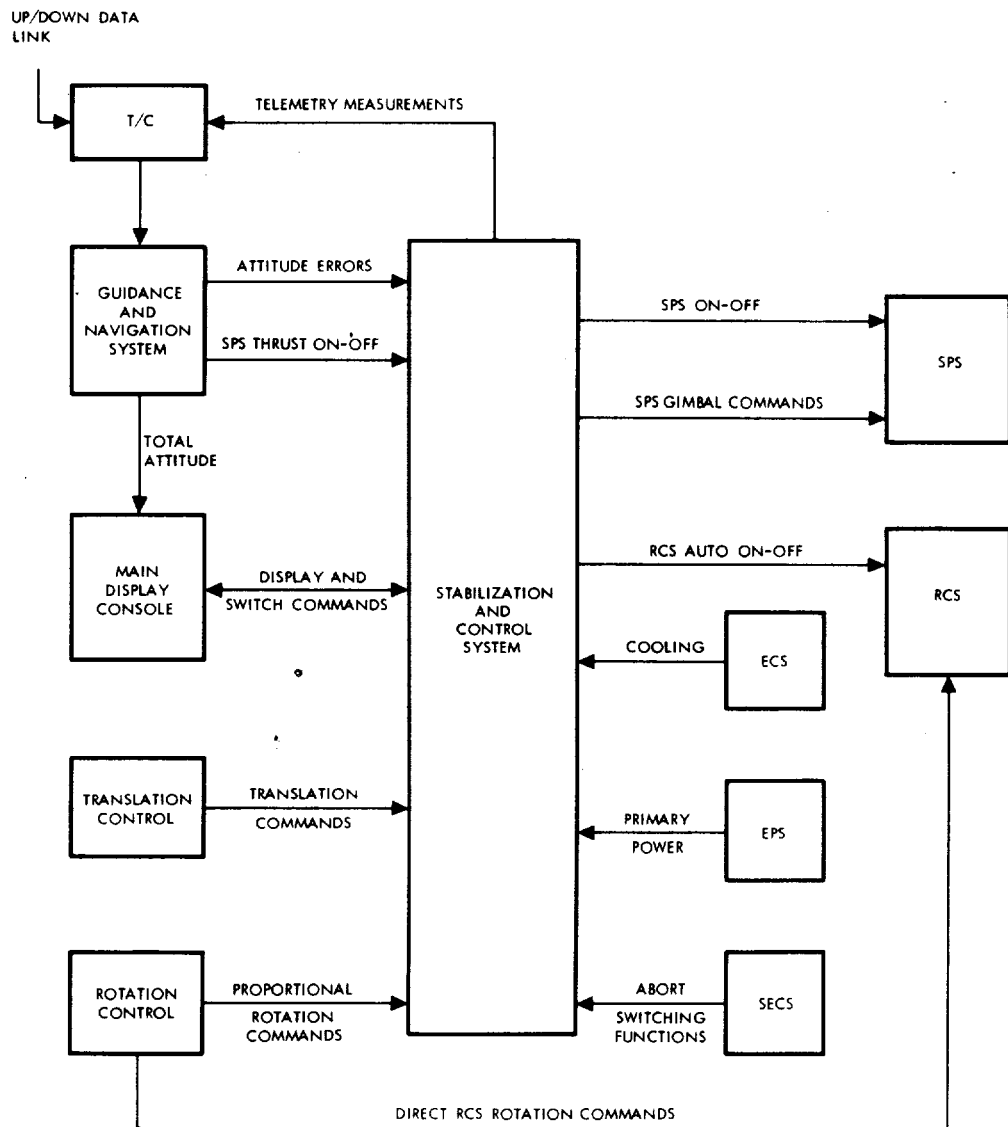
Transfers heat from SCS electronics

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STABILIZATION AND CONTROL SYSTEM

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Figure 2.3-1. SCS Functional Interface

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- Sequential Events Control System (SECS)

Provides abort switching function

By switch control in SCS, initiates abort and enables control functions in SCS

SCS

- Guidance and Navigation System (G&N)

Provides roll, pitch, and yaw total attitude inputs to SCS

Provides attitude error signals

Provides thrust on/off command for SPS engine

Provides steering commands to TVC during G&N  $\Delta V$

- Propulsion Systems (SPS, RCS).

The service propulsion system generates internal forces for large velocity changes

The reaction control system generates the internal forces required for rotation, and translation.

A detailed description and function of the SCS controls and displays referred to is provided in section 3.

## 2.3.2 FUNCTIONAL DESCRIPTION.

The functional description of the SCS covers the major areas of control capabilities, Apollo reference axes, and subsystem description.

### 2.3.2.1 Control Capabilities.

Control capability exists for the manual attitude control, automatic attitude control, and thrust vector control functions. The following paragraphs provide a brief discussion of each control function.

#### 2.3.2.1.1 Manual Attitude Control.

Manually commanded inputs converted to electrical signals, directly or indirectly, cause the propulsion systems to maneuver the spacecraft to a desired attitude and/or change the flight path (trajectory) of the spacecraft. Manual controls include two independent rotation controllers (figure 2.3-8), two translation controllers (figure 2.3-8), and an arrangement of panel-mounted controls and displays.

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## STABILIZATION AND CONTROL SYSTEM

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2.3.2.3 Subsystems.

The attitude reference, attitude control, and thrust vector control subsystems are described in the following paragraphs. The description covers the purpose and functions of each subsystem, and the integrated association with other systems. Figures 2.3-3 and 2.3-4, provide simplified block, and flow diagrams of the three subsystems and figure 2.3-5 shows the switching logic and functions which affect the three subsystems.

2.3.2.3.1 Attitude Reference Subsystem.

The purpose of the attitude reference subsystem (figures 2.3-4 and 2.3-5) is to relate the S/C attitude in terms of its geometric X, Y, and Z coordinate system to an arbitrarily chosen coordinate system with a fixed reference frame. The relation between the two coordinate systems represents inertial attitude and is presented to the astronauts by visual display.

Visual observation of inertial attitude is necessary to perform manual maneuvers or for monitoring automatic operations. The flight director attitude indicator (FDAI), located on the S/C main display console, displays the information required for the manual and automatic operations. The information displayed includes S/C total attitude, attitude error in three axes, and rotational rates in three axes. The information displayed by the FDAI is obtained from either the G&N system or the SCS.

There are two attitude references associated with the attitude reference subsystem: primary and backup. The primary reference is obtained through the mechanization of subsystems within the G&N system. The backup reference is mechanized within the SCS. Each of the attitude reference loops contain three basic elements: a computer, an inertial reference device, and a visual display.

Attitude Reference/G&N. To obtain an inertial reference using the G&N system, the astronauts, the G&N optics subsystem, the inertial and computer subsystems, and the MSFN are integrated to form a closed loop system.

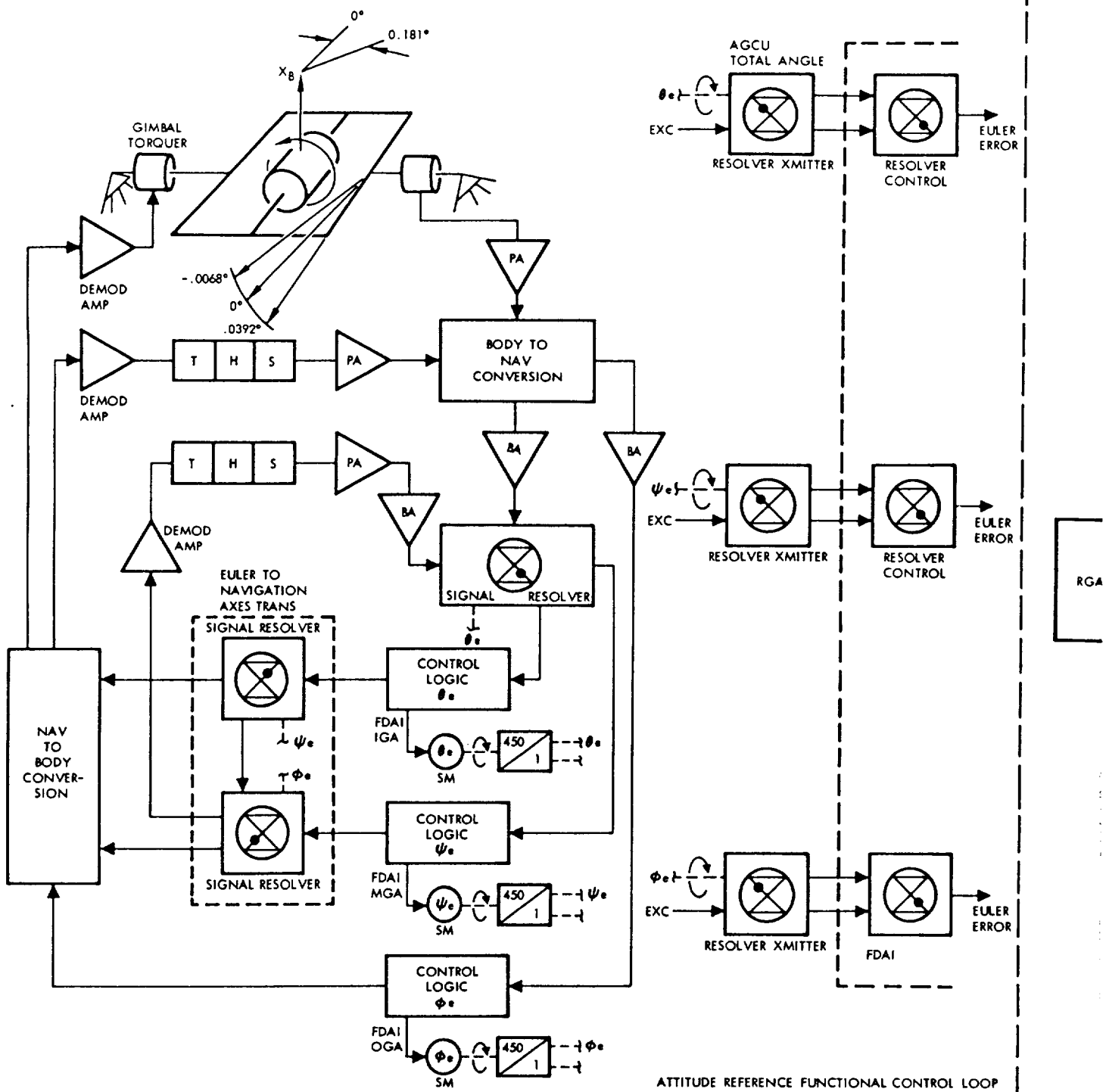
The G&N system is used to determine inertial attitude and position and initiates alignment of the stable element of the IMU to the desired inertial reference initially established by optical sightings.

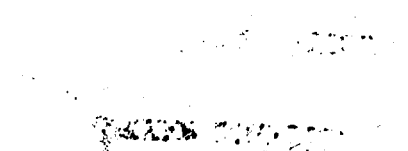
After IMU alignment, the IMU in conjunction with the AGC can provide inertial-referenced attitude hold and, if required, inertial-referenced velocity changes. Translational velocities are sensed by accelerometers mounted on the IMU stable element. The AGC processes the accelerometer signals to update velocity and change information for TVC functions.

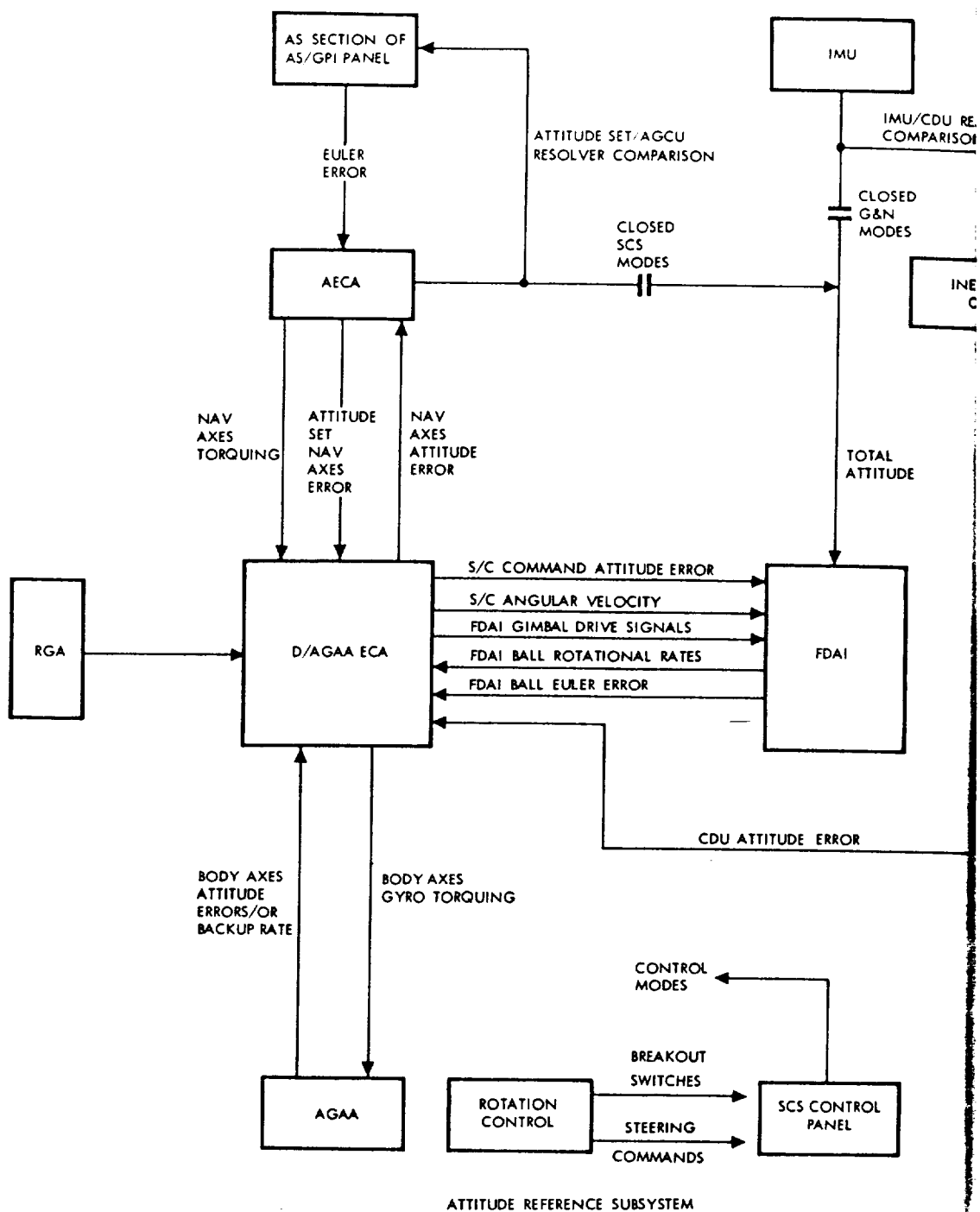
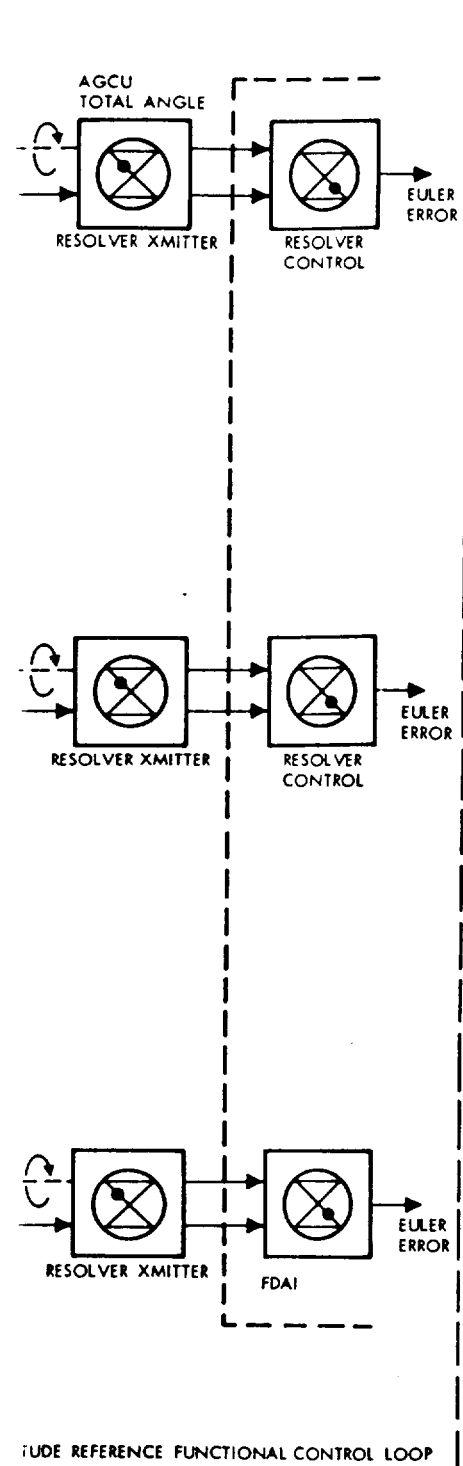
In addition to the optical alignment of the IMU, the astronauts can use the computer subsystem to establish IMU alignment.

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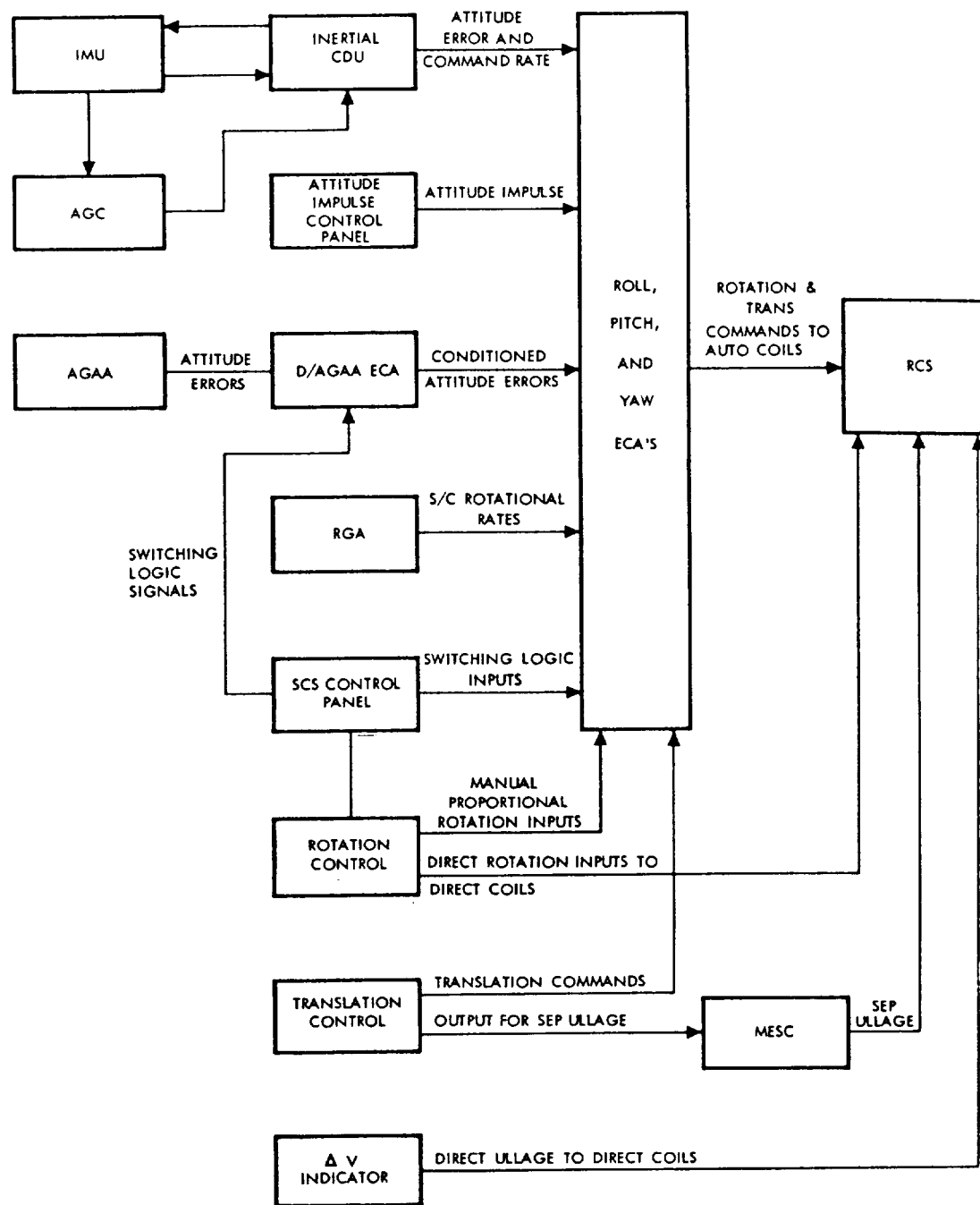
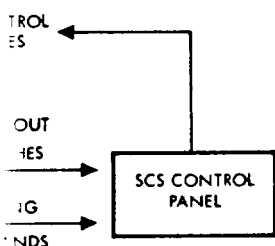
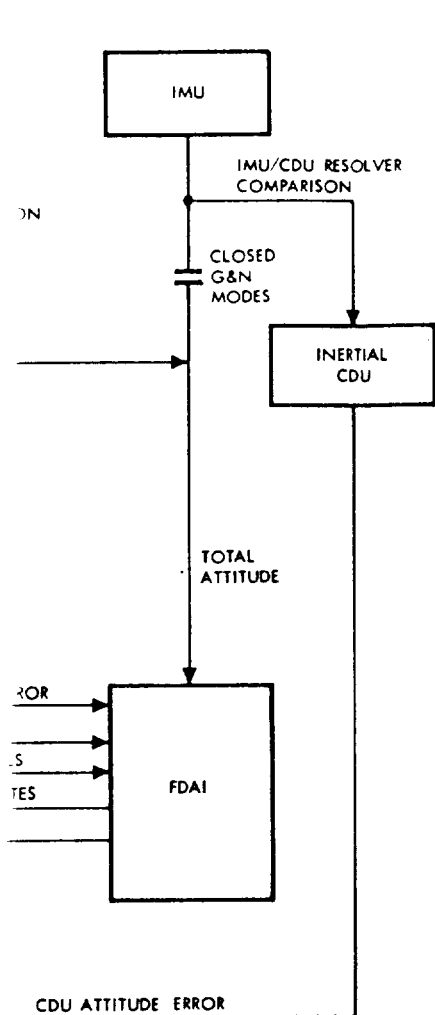






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*Journal of Management Studies*, 19(6), 701-718.

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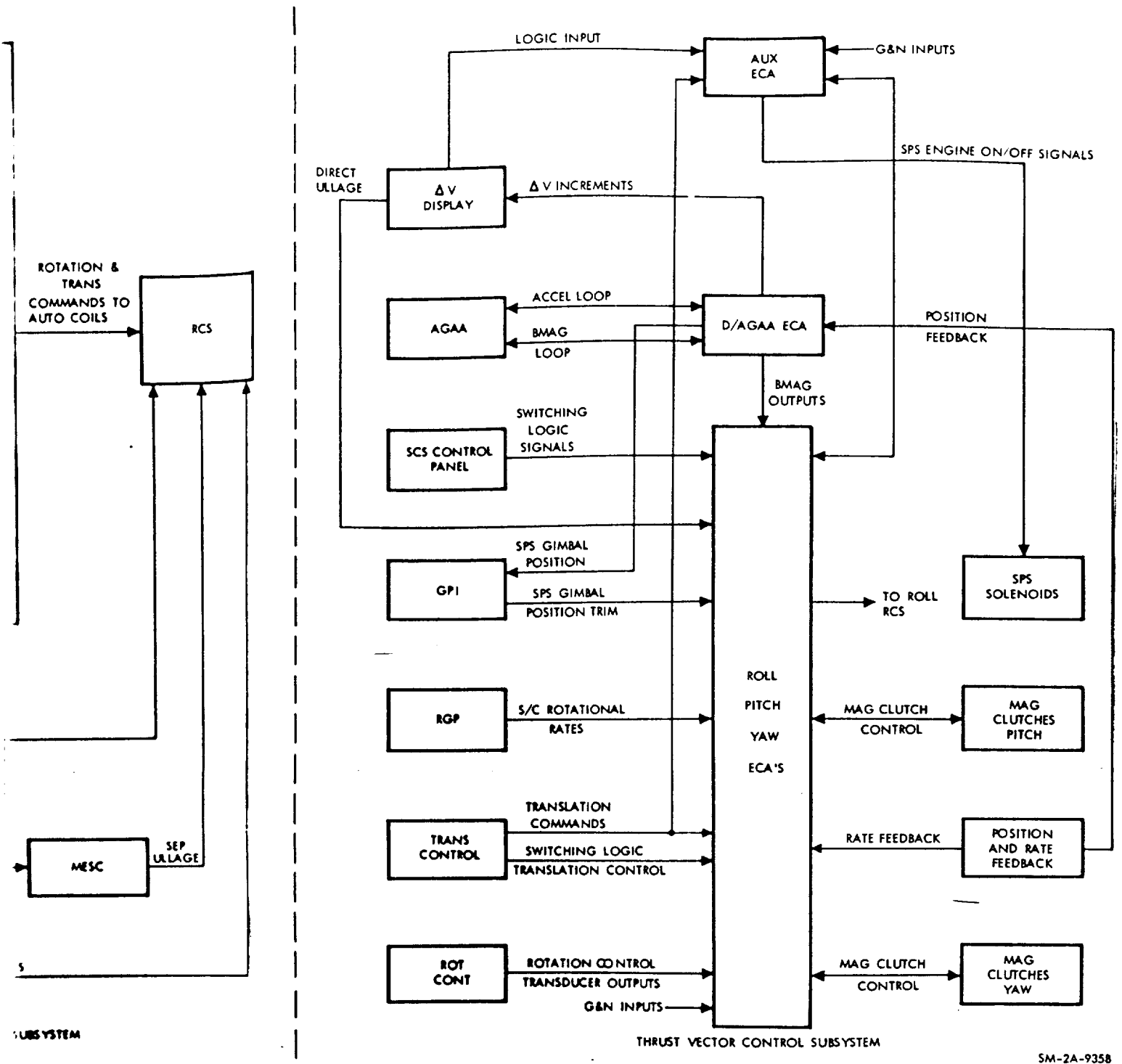


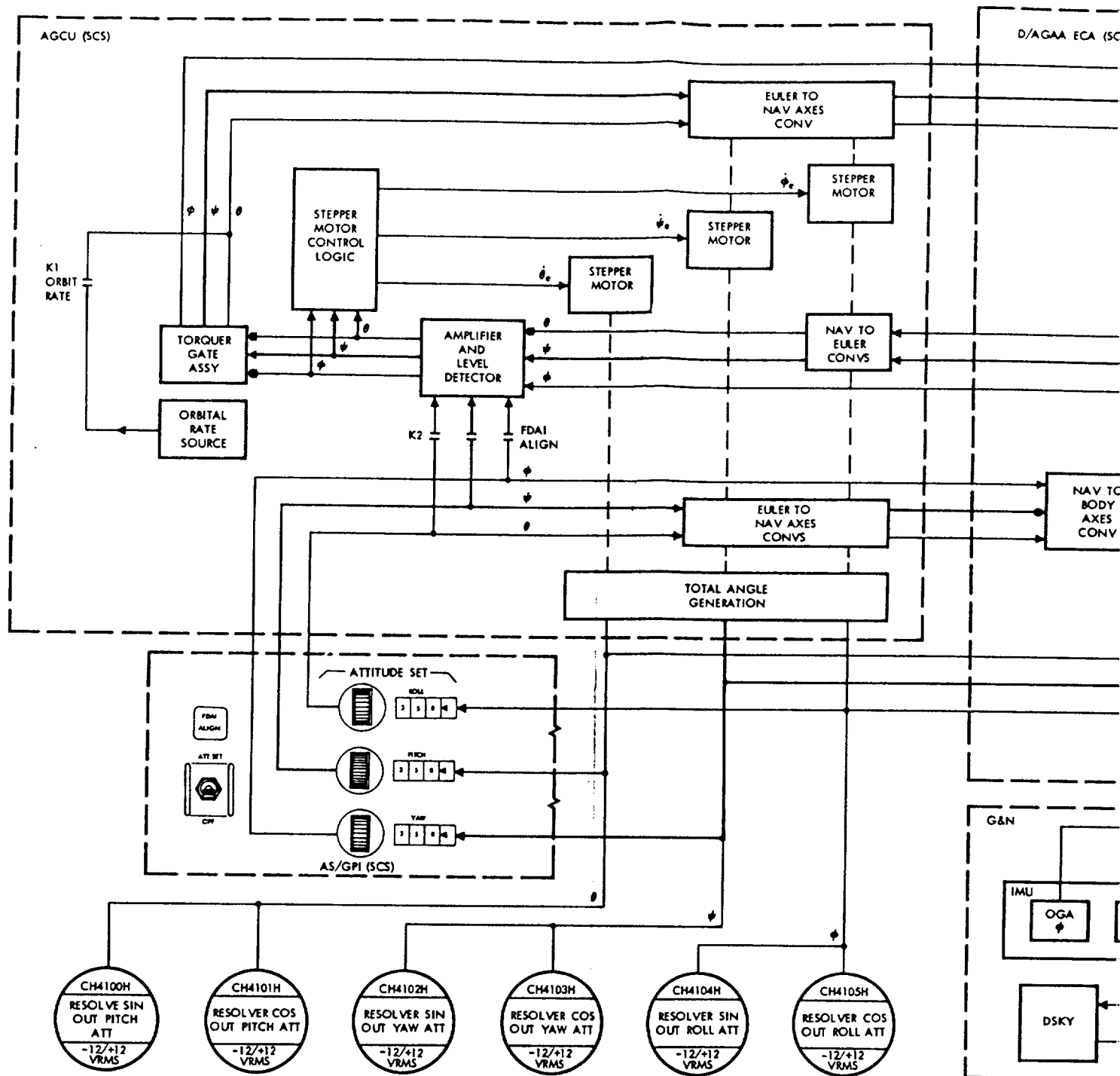
Figure 2.3-3. SCS Functional Block Diagram

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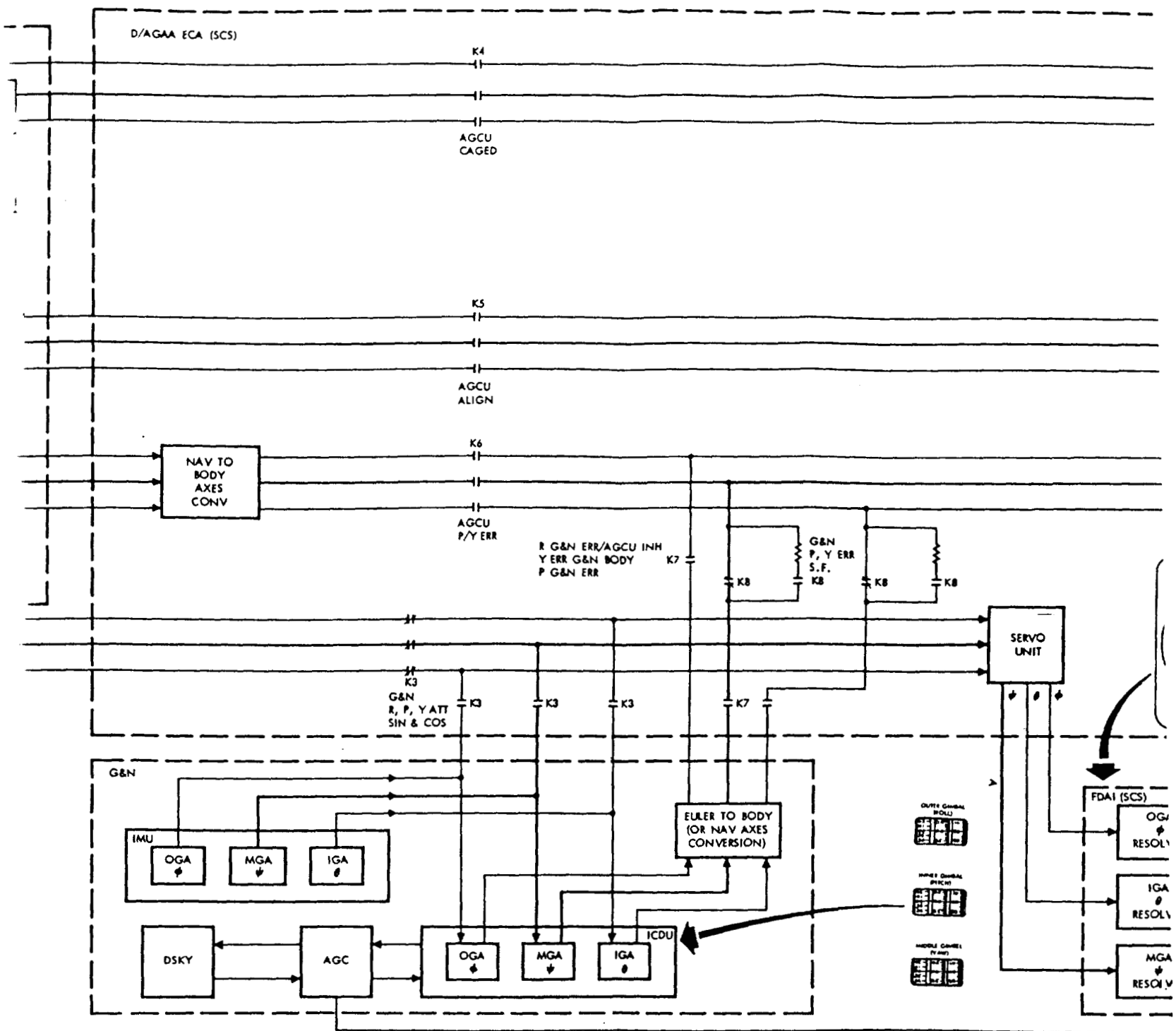
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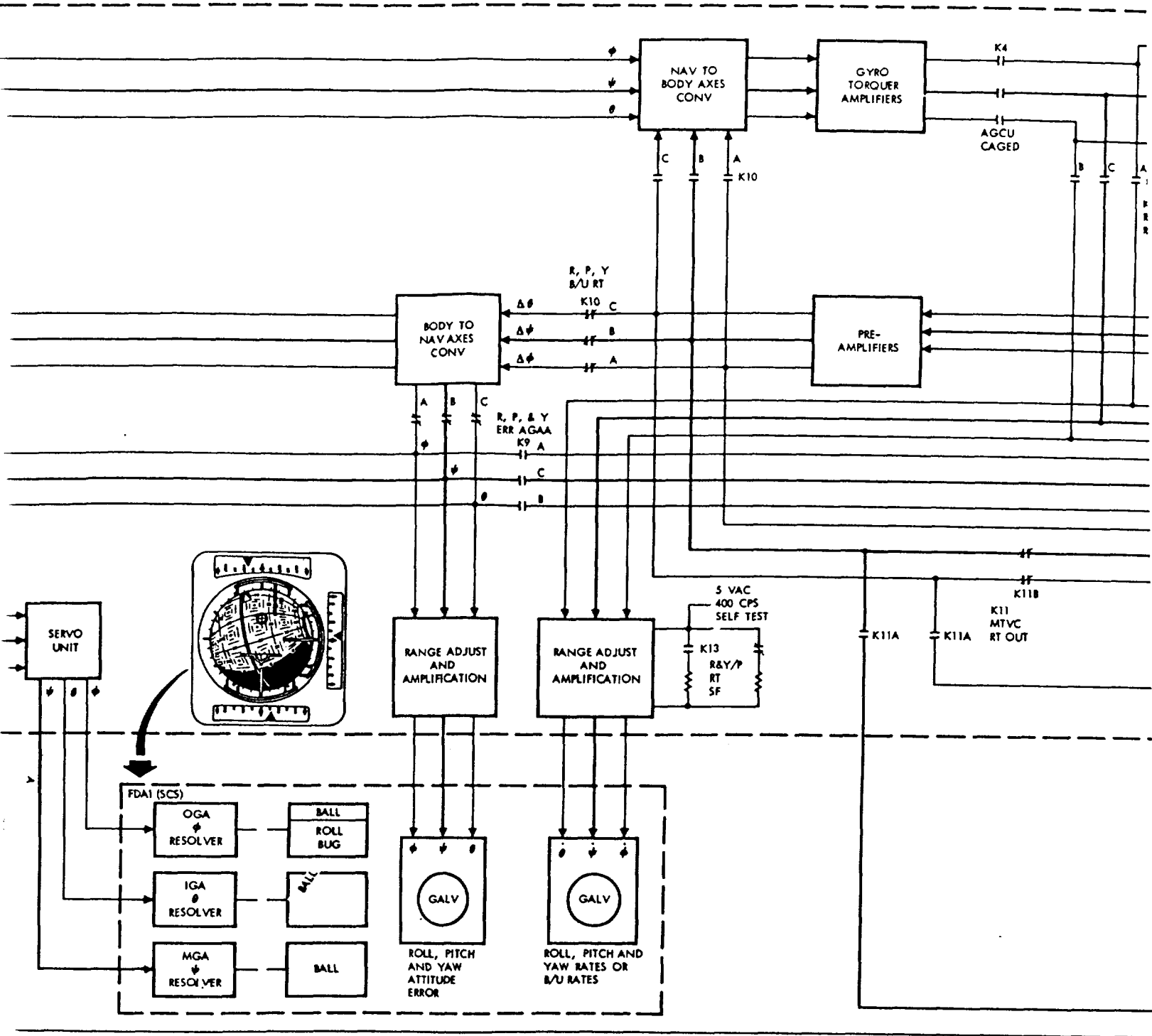
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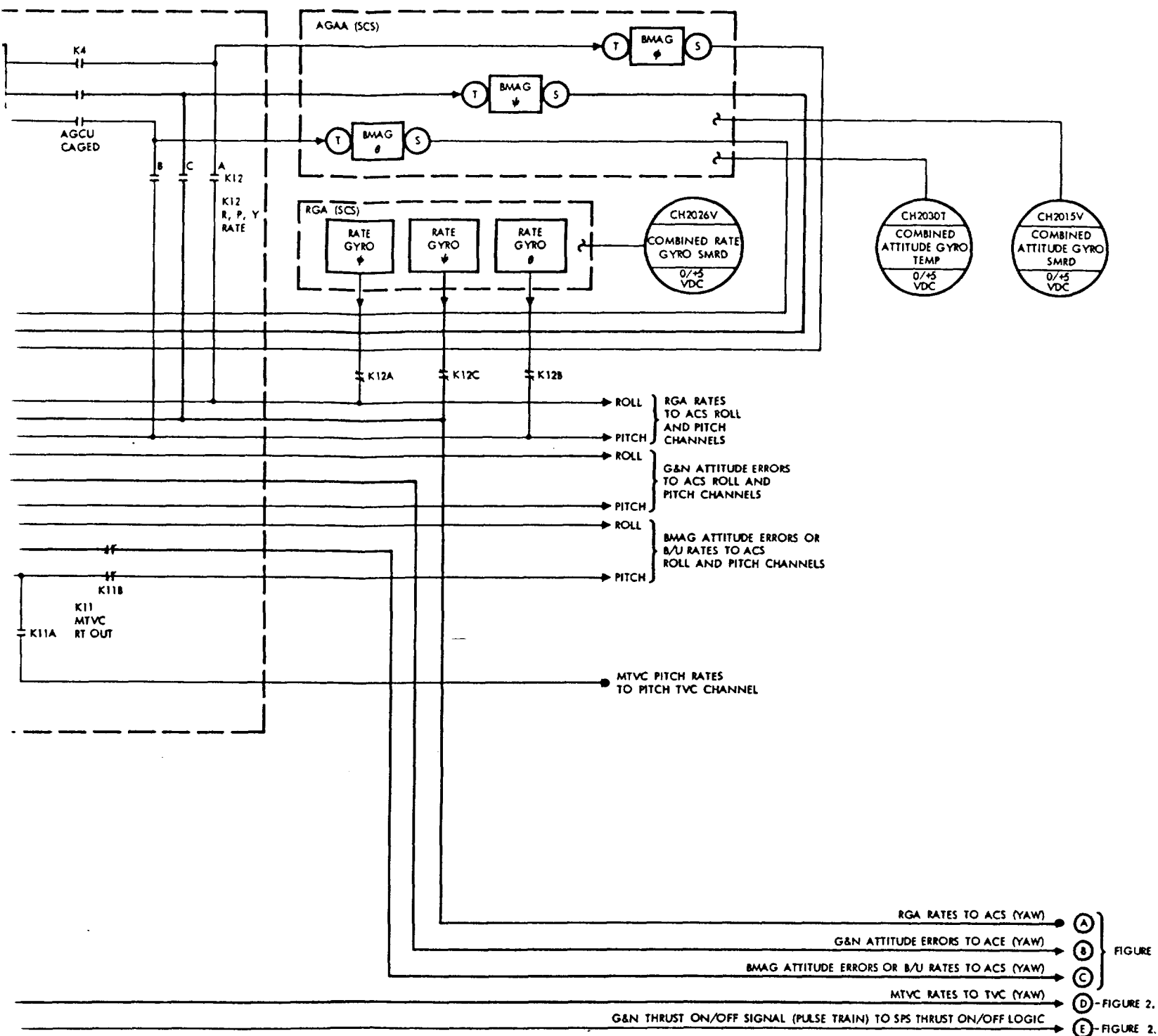


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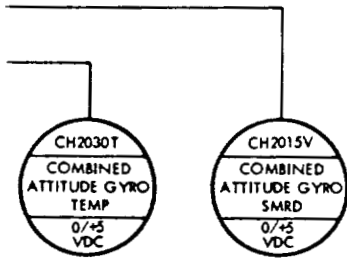
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SYSTEMS DATA



	<div>ORBIT RATE</div> <div>FDAI ALIGN</div> <div>G&amp;N R, P, Y ATT SINE COS</div> <div>AGCU CAGED</div> <div>AGCU ALIGN</div> <div>AGCU P/V ERROR</div> <div>R G&amp;N ERR/AGCU WH G&amp;N P ERROR Y ERR G&amp;N BODY</div> <div>G&amp;N P, Y ERR S.F.</div> <div>R, P, Y ERROR AGAA</div> <div>R, P, Y B/U RATE</div> <div>MTVC RT OUT</div> <div>R, P, Y RATE</div> <div>R &amp; Y/P S.F.</div>												
MAJOR MODE	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13
MONITOR			•	•	•		•	•	•	•			
G&N ATTITUDE CONTROL			•	•	•		•		•				
SCS ATTITUDE CONTROL													
SCS LOCAL VERTICAL	•			•									
G&N ΔV			•				•		•				
SCS ΔV													
G&N ENTRY			•	•	•		•		•				
SCS ENTRY													•
INTEGRATED MODE FUNCTIONS													
CSS				•	•								
MINIMUM IMPULSE CONTROL				•	•								
TRANSLATION CONTROL "CW" SWITCH				•	•								
MTVC										•	•	•	
B/U RATE - R, P, & Y									•	•		•	
.05G MANUAL (SCS ENTRY)				•	•				•				
CHANNEL DISABLE (SCS ATT CONT)				•	•								
ATT SET SW ON (SCS MODES)						•			•				
FDAI ALIGN		•											
SELF TEST												•	•

- RGA RATES TO ACS (YAW) → (A)
- G&N ATTITUDE ERRORS TO ACE (YAW) → (B)
- ERRORS OR B/U RATES TO ACS (YAW) → (C)
- MTVC RATES TO TVC (YAW) → (D)
- (IN) TO SPS THRUST ON/OFF LOGIC → (E)

FIGURE 2.3-4, SHEET 2

FIGURE 2.3-4, SHEET 3

FIGURE 2.3-4, SHEET 4

NOTE: For Switching Logic Details,  
See Figure 2.3-5, Sheet 2

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Figure 2.3-4. SCS Functional Flow Diagram (Sheet 1 of 4)

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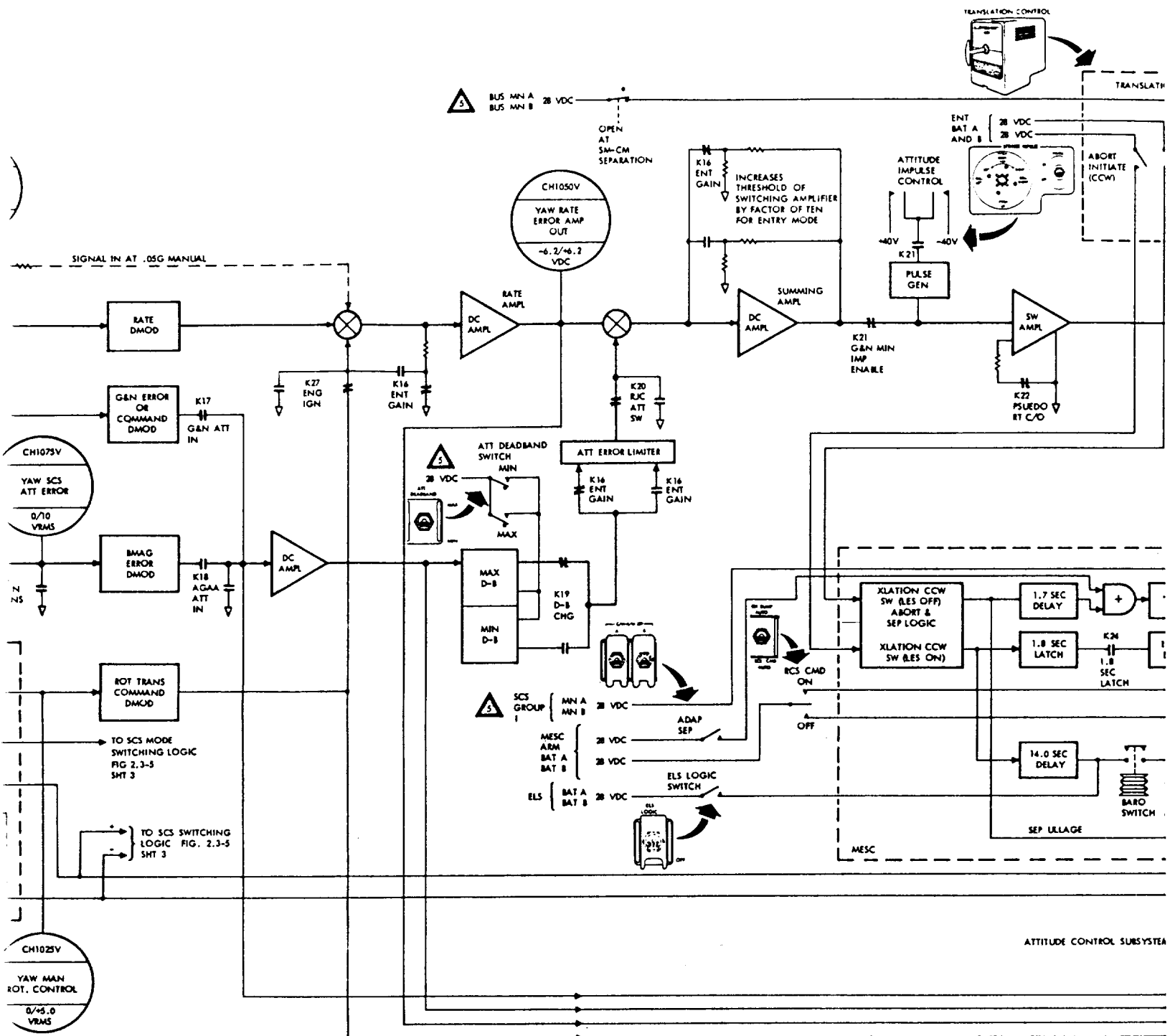
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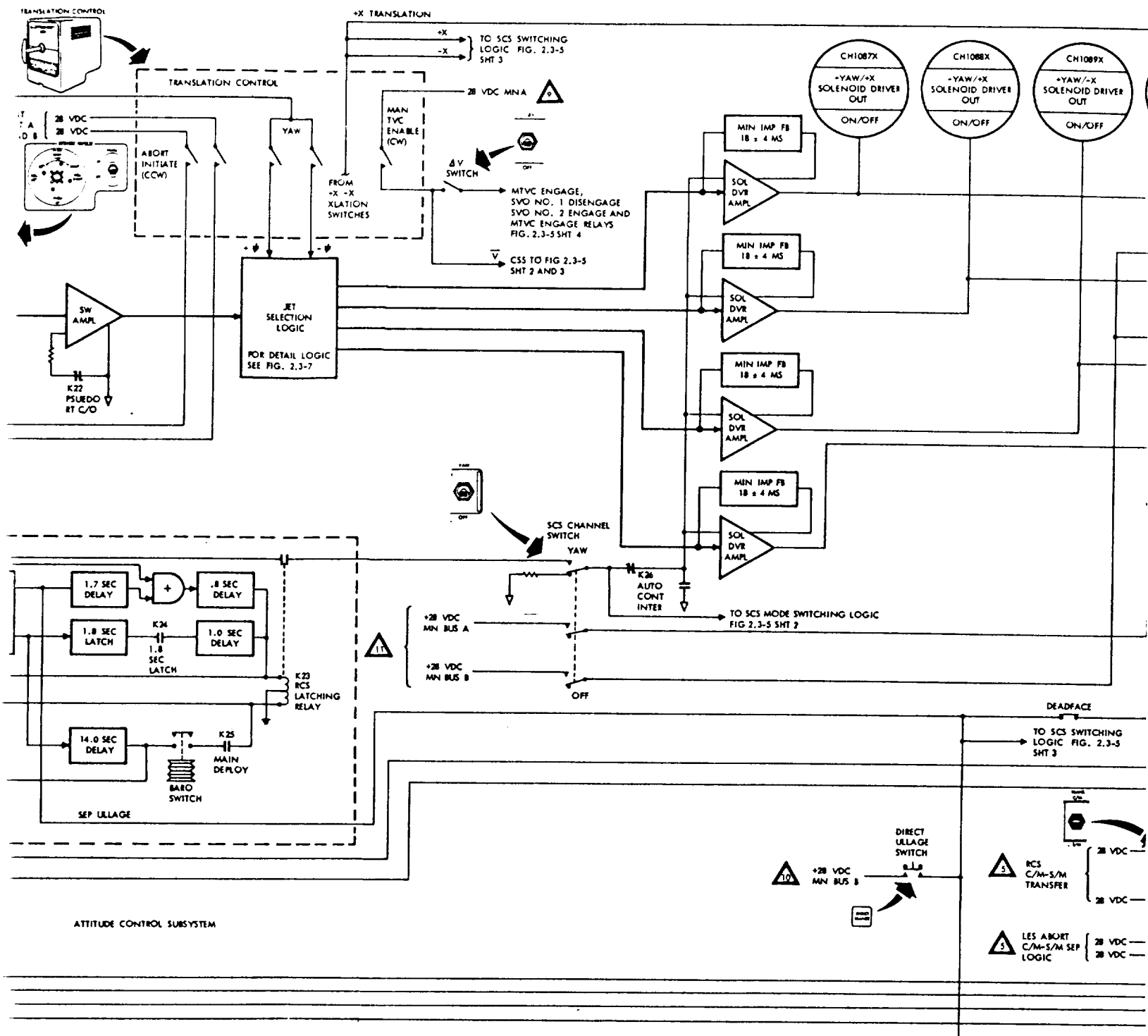
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SYSTEMS DATA

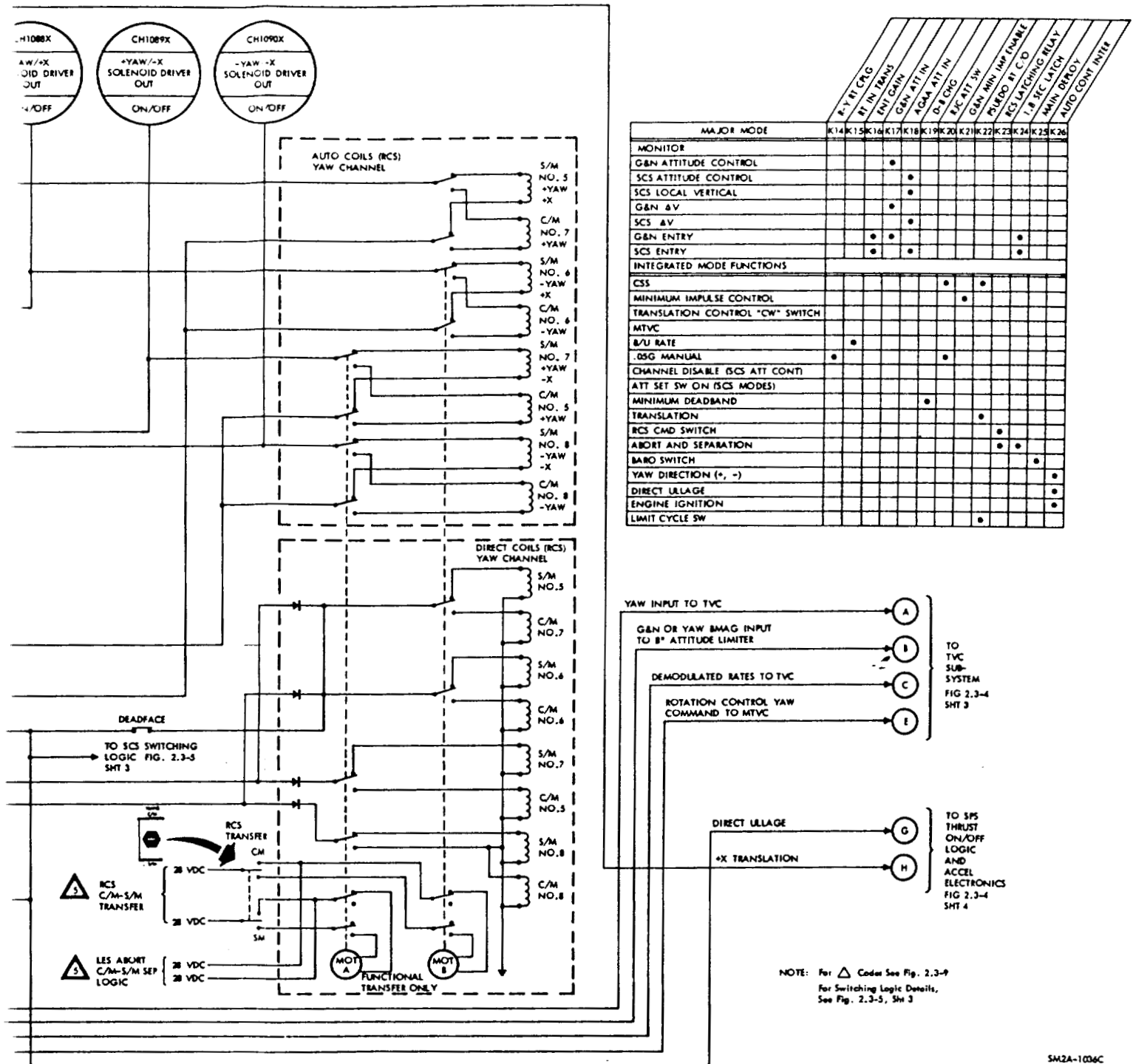


Figure 2.3-4. SCS Functional Flow Diagram (Sheet 2 of 4)

STABILIZATION AND CONTROL SYSTEM

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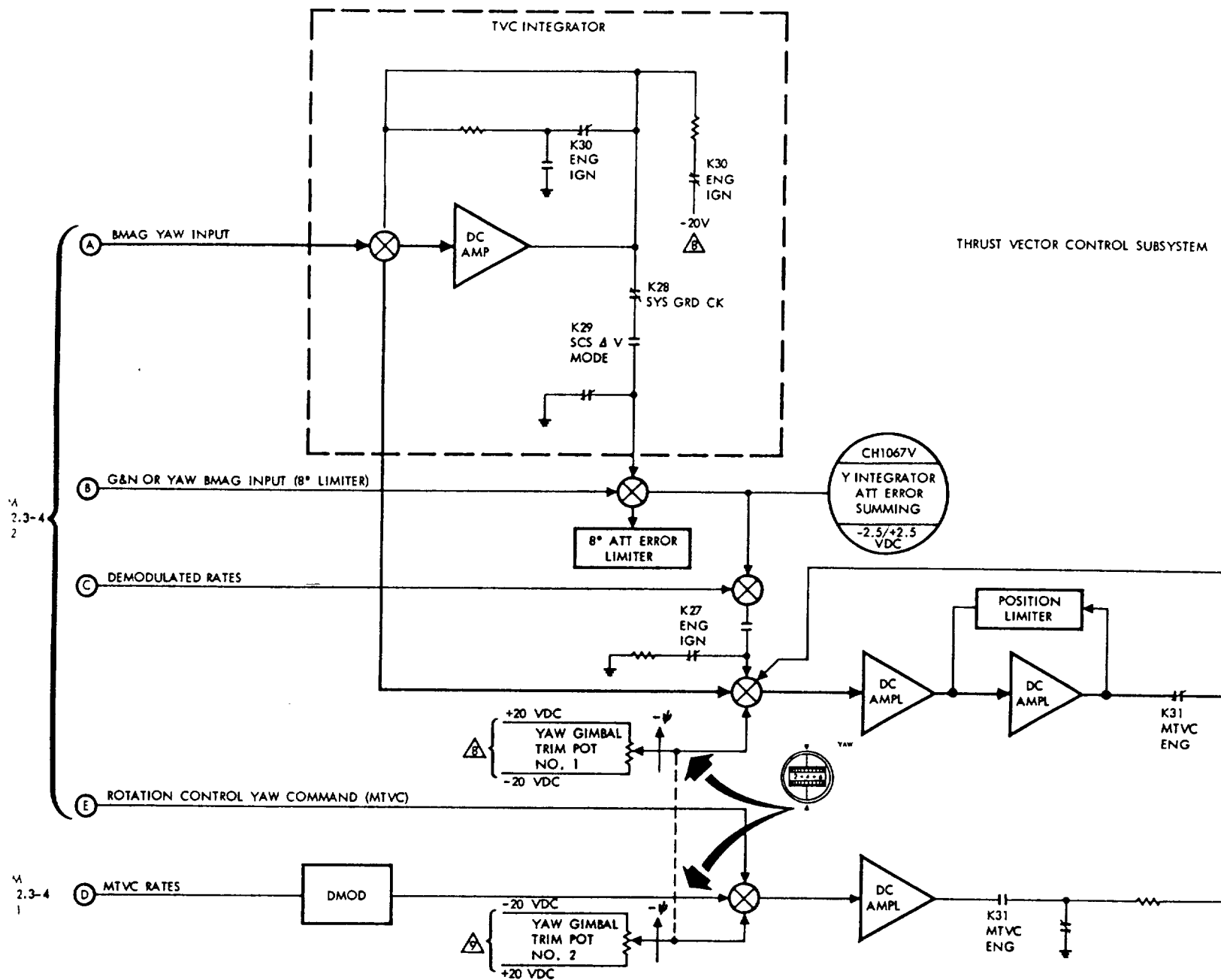
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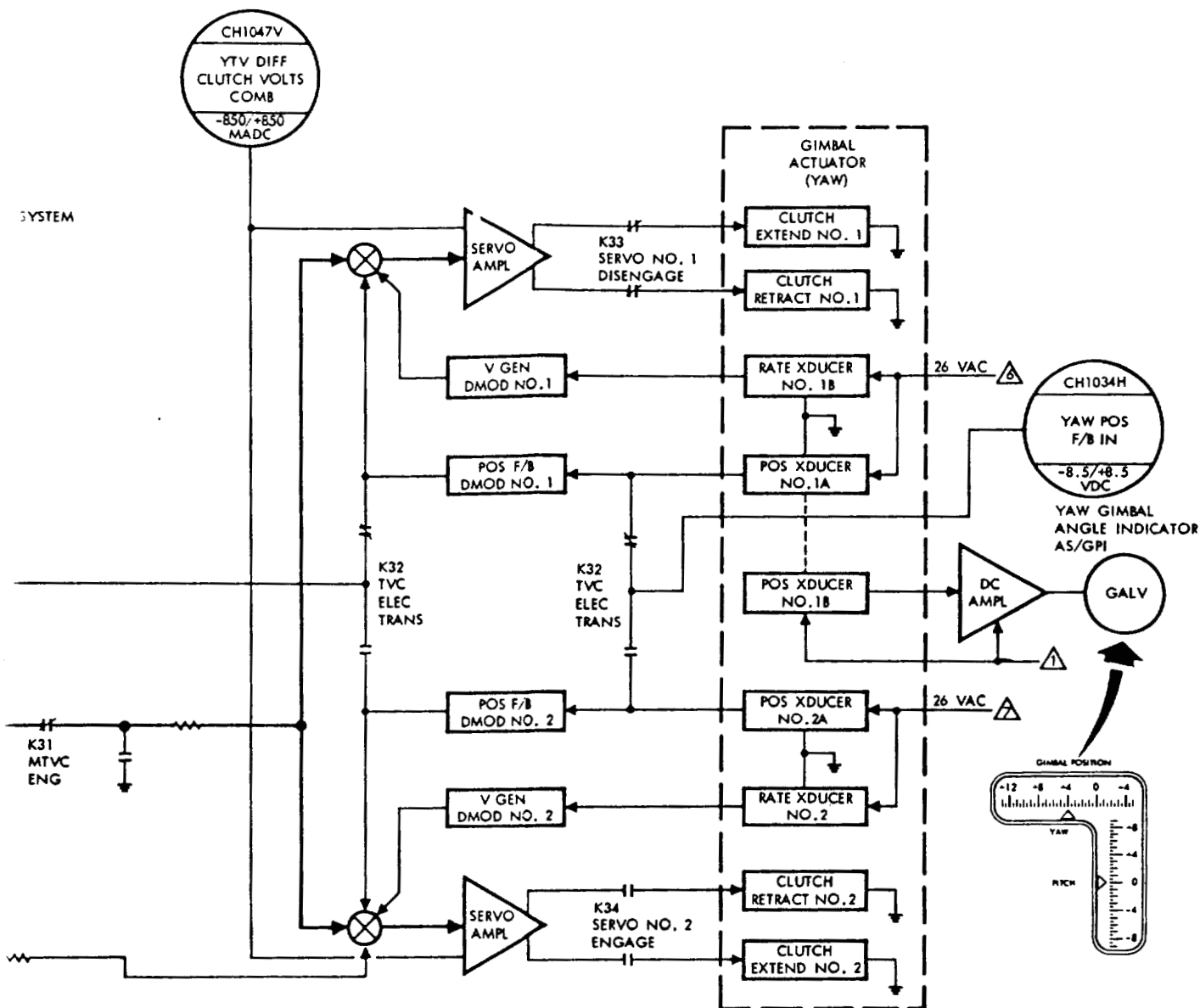


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SYSTEMS DATA

SCS



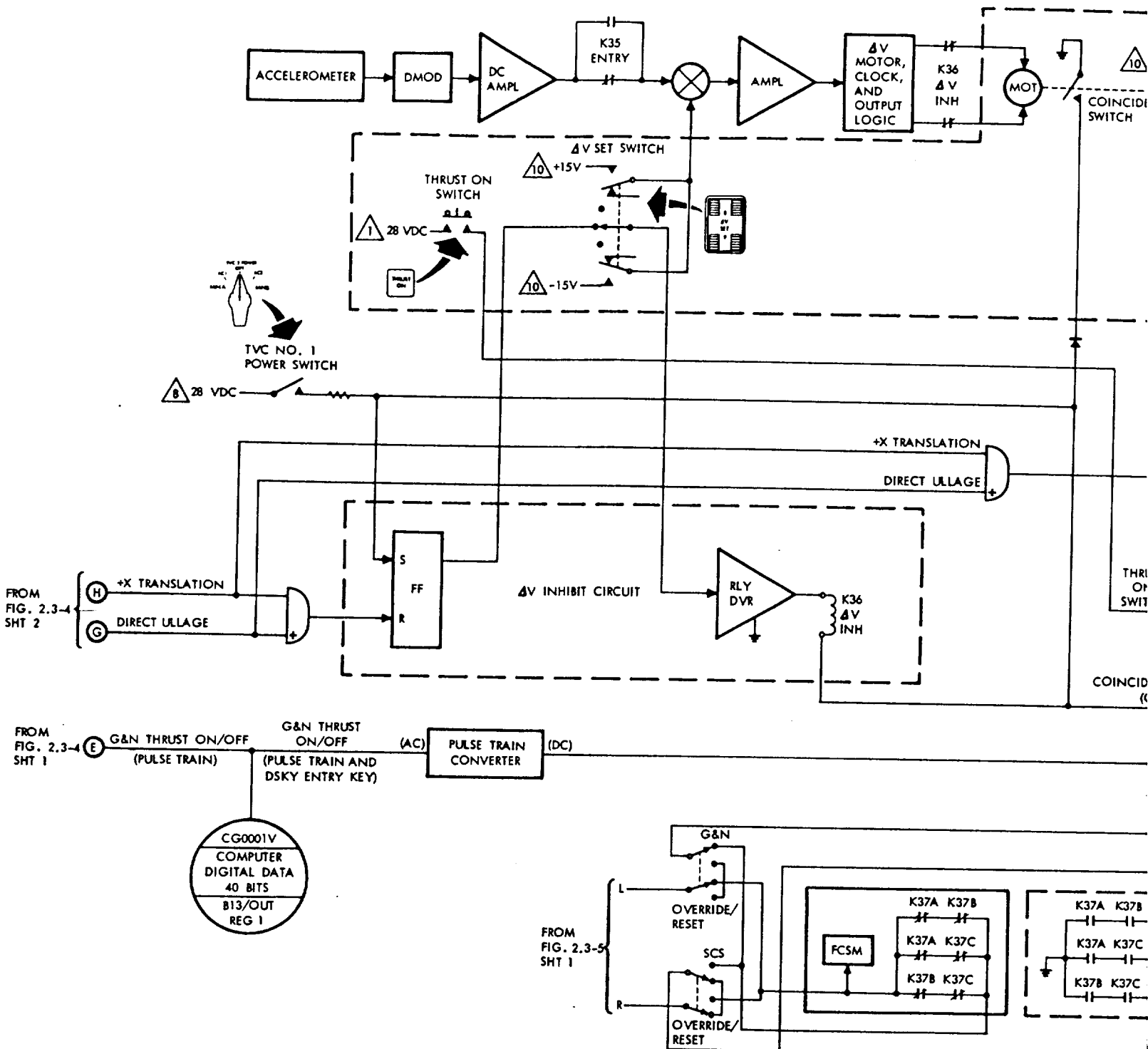
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Figure 2.3-4. SCS Functional Flow Diagram (Sheet 3 of 4)

STABILIZATION AND CONTROL SYSTEM

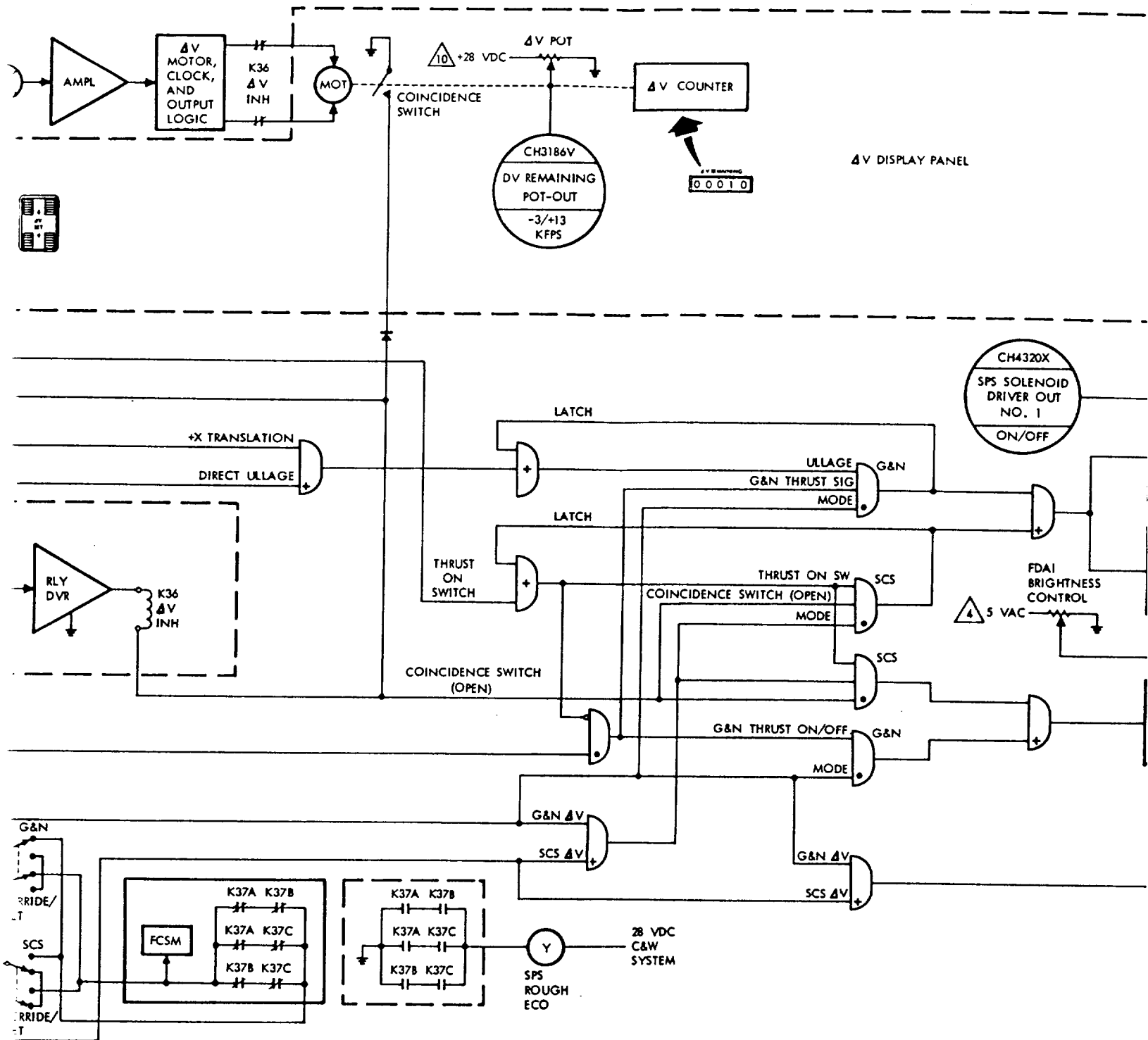
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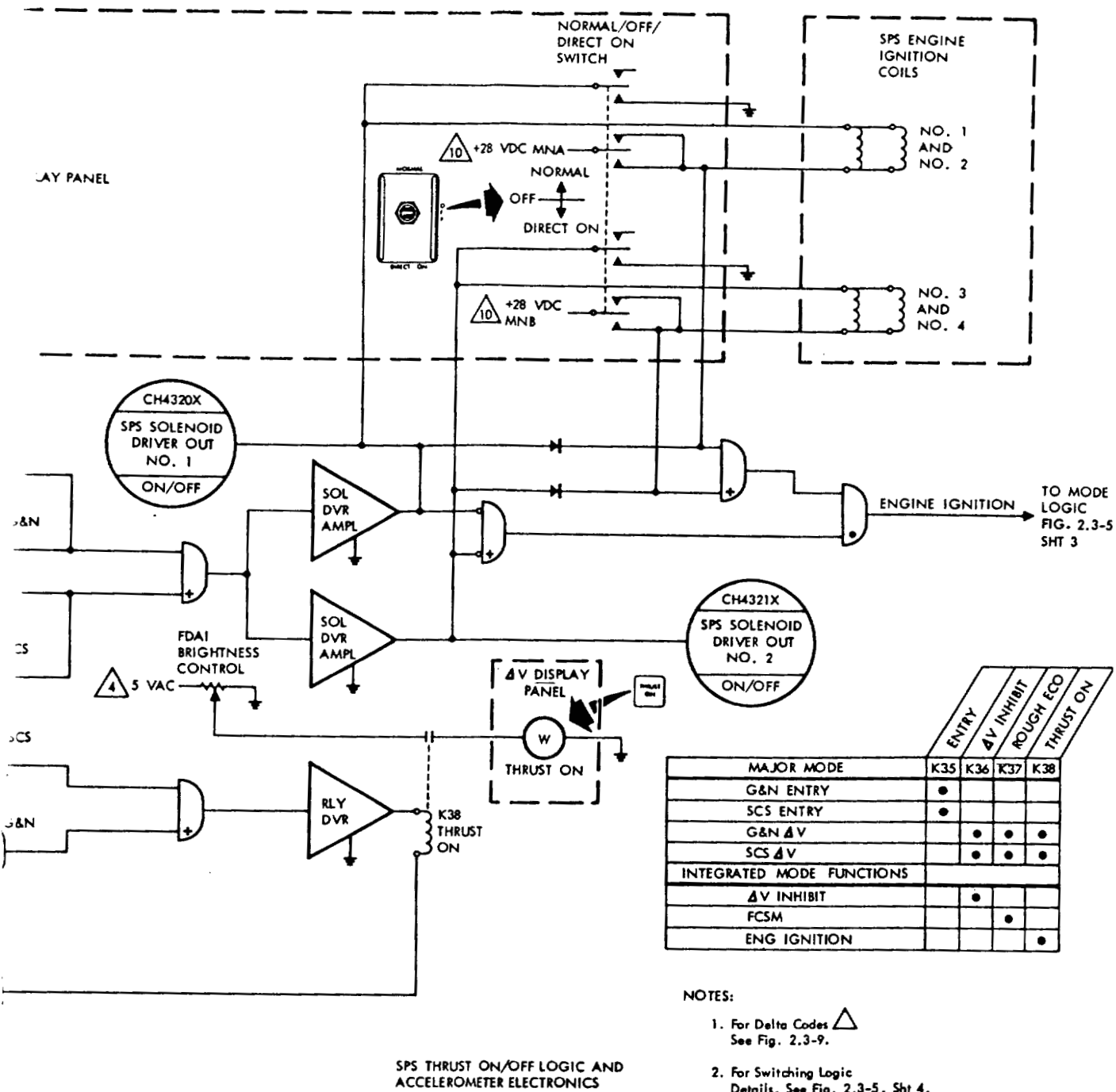
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SYSTEMS DATA



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Figure 2.3-4. SCS Functional Flow Diagram (Sheet 4 of 4)

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SYSTEMS DATA

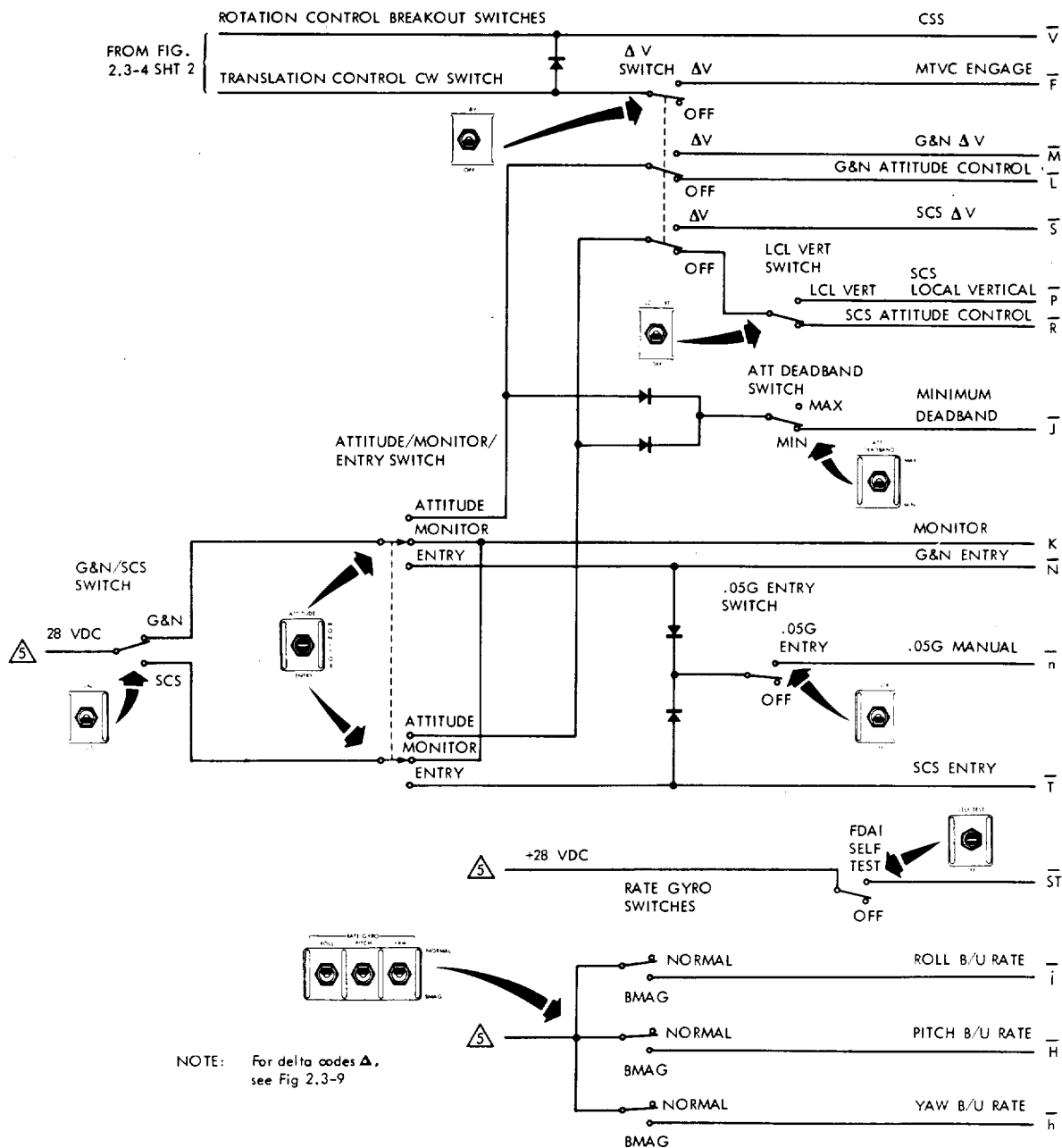
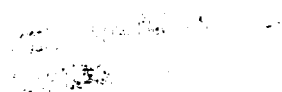


Figure 2.3-5. SCS Switching Logic (Sheet 1 of 4)

STABILIZATION AND CONTROL SYSTEM



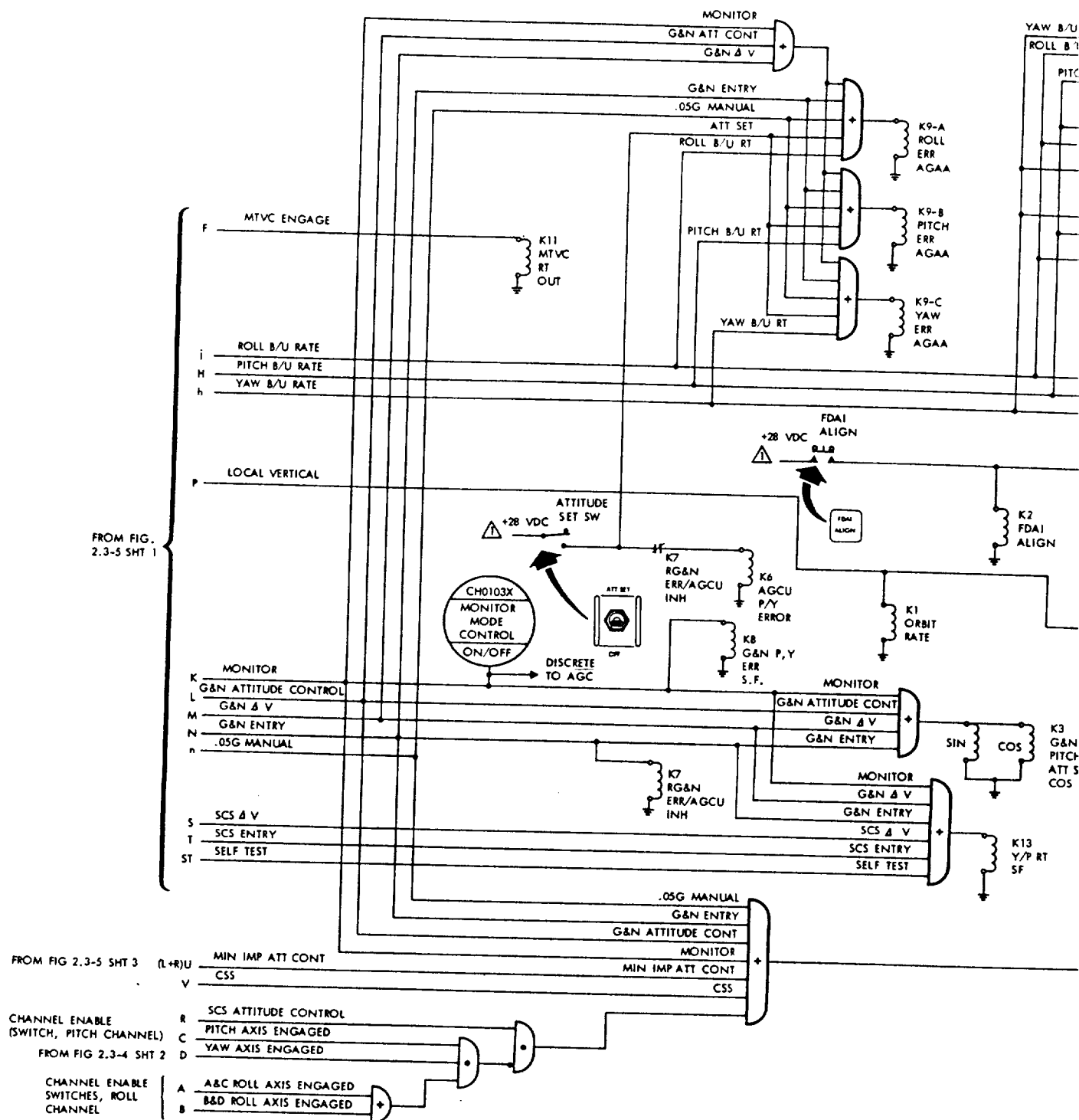


Figure 2.3-5. S

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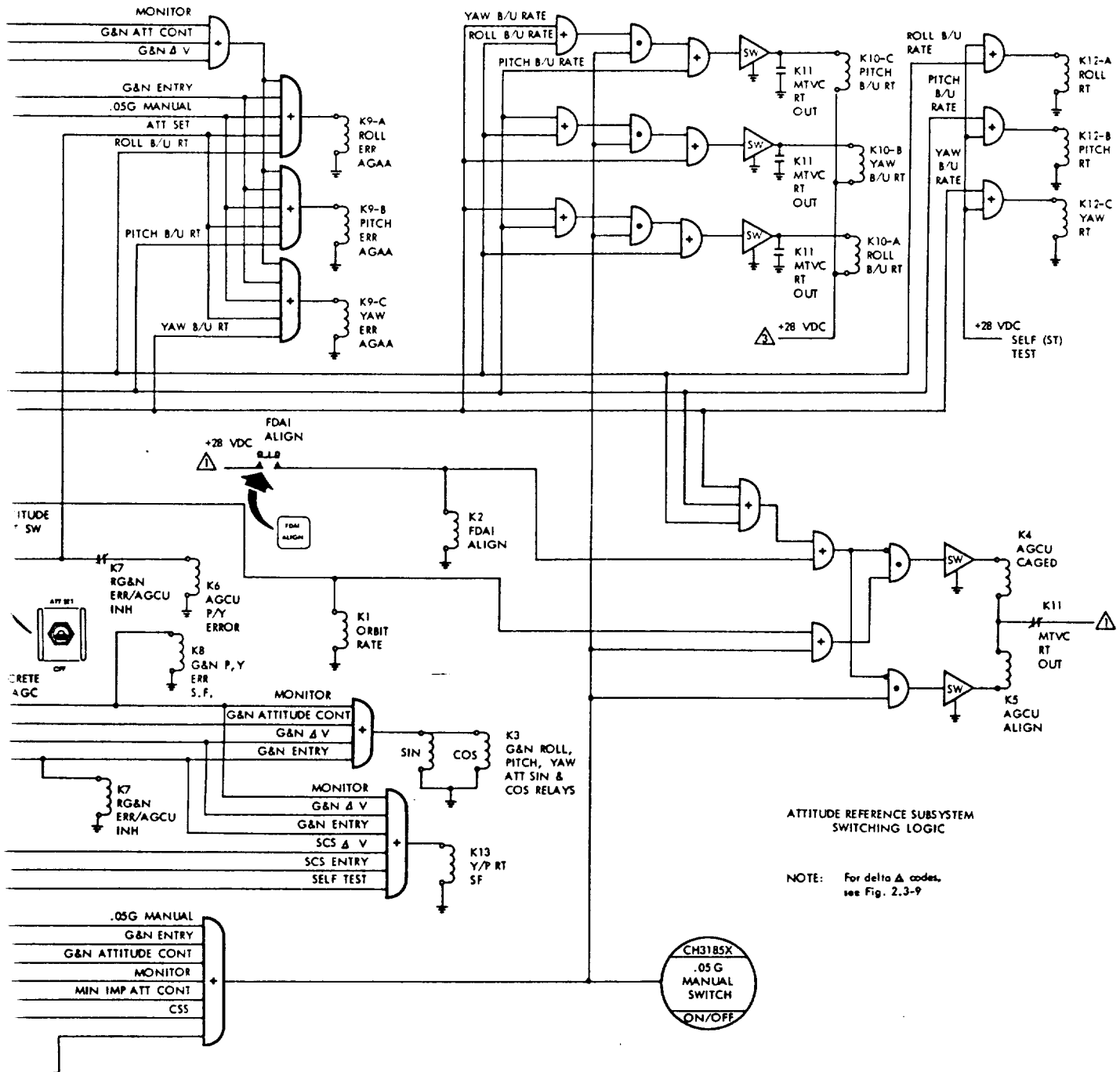


Figure 2.3-5. SCS Switching Logic (Sheet 2 of 4)

STABILIZATION AND CONTROL SYSTEM

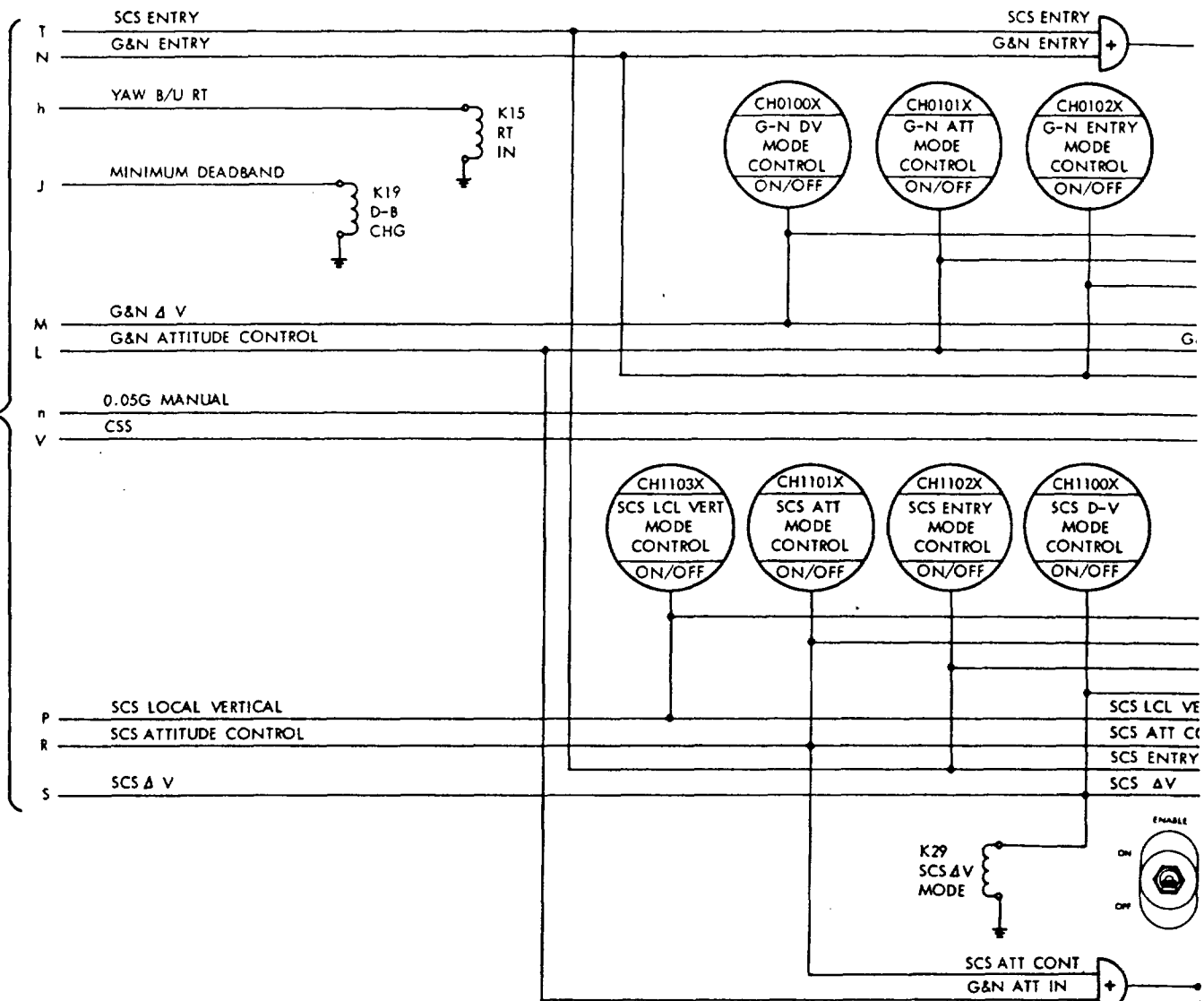
Mission \_\_\_\_\_ Basic Date 12 Nov 1966 Change Date \_\_\_\_\_ Page 2.3-21/2.3-22

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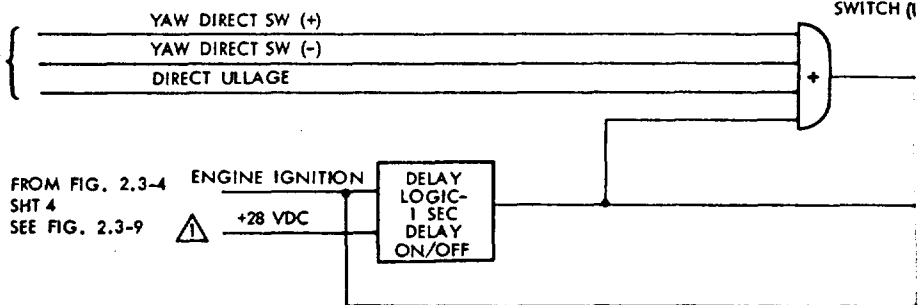




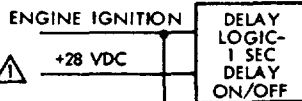
FROM  
SCS  
MODE  
SWITCHES  
FIG. 2.3-5  
SHT 1



FROM FIG. 2.3-4  
SHT 2



FROM FIG. 2.3-4  
SHT 4  
SEE FIG. 2.3-9



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 SYSTEMS DATA

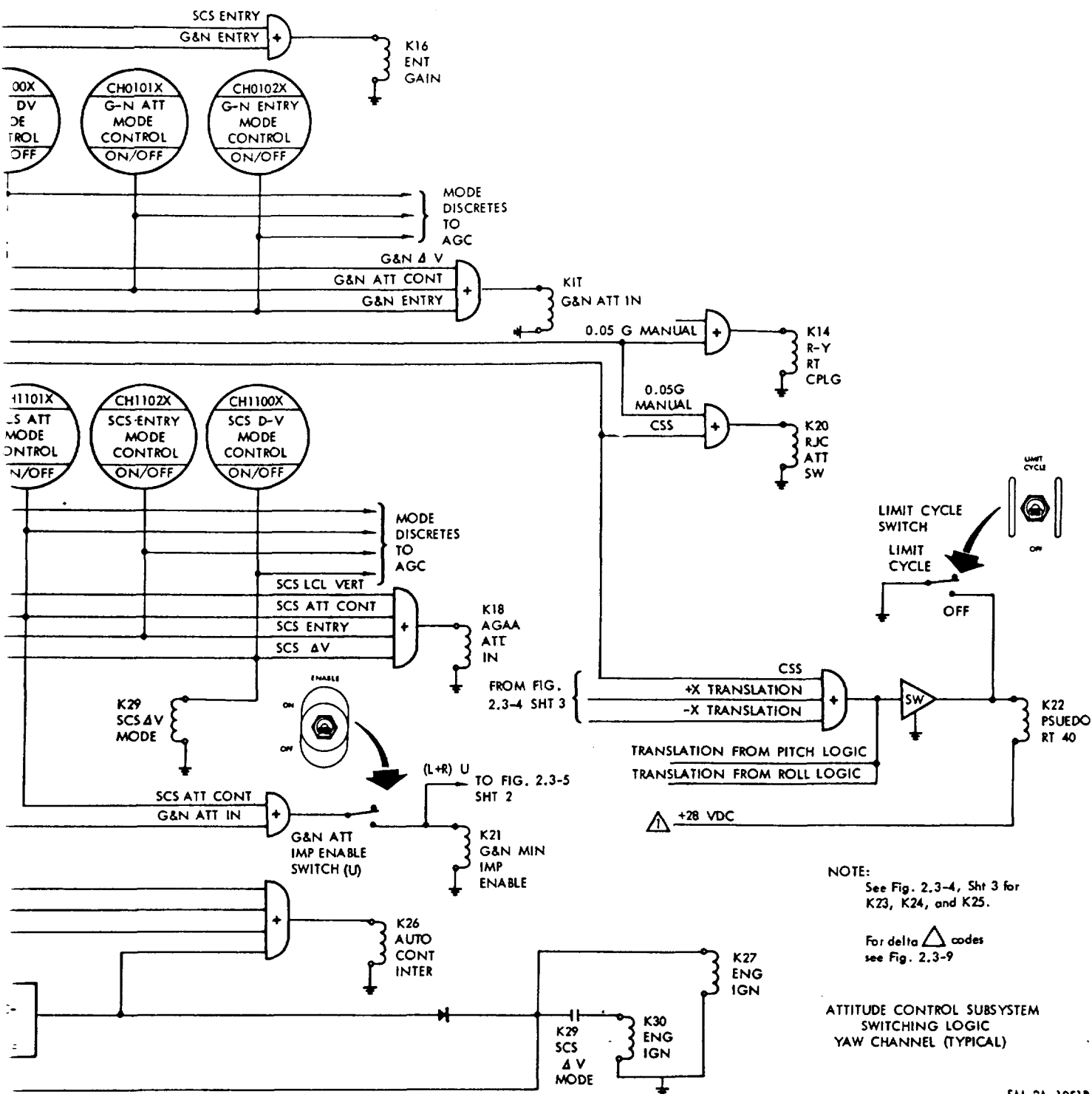


Figure 2.3-5. SCS Switching Logic (Sheet 3 of 4)

STABILIZATION AND CONTROL SYSTEM

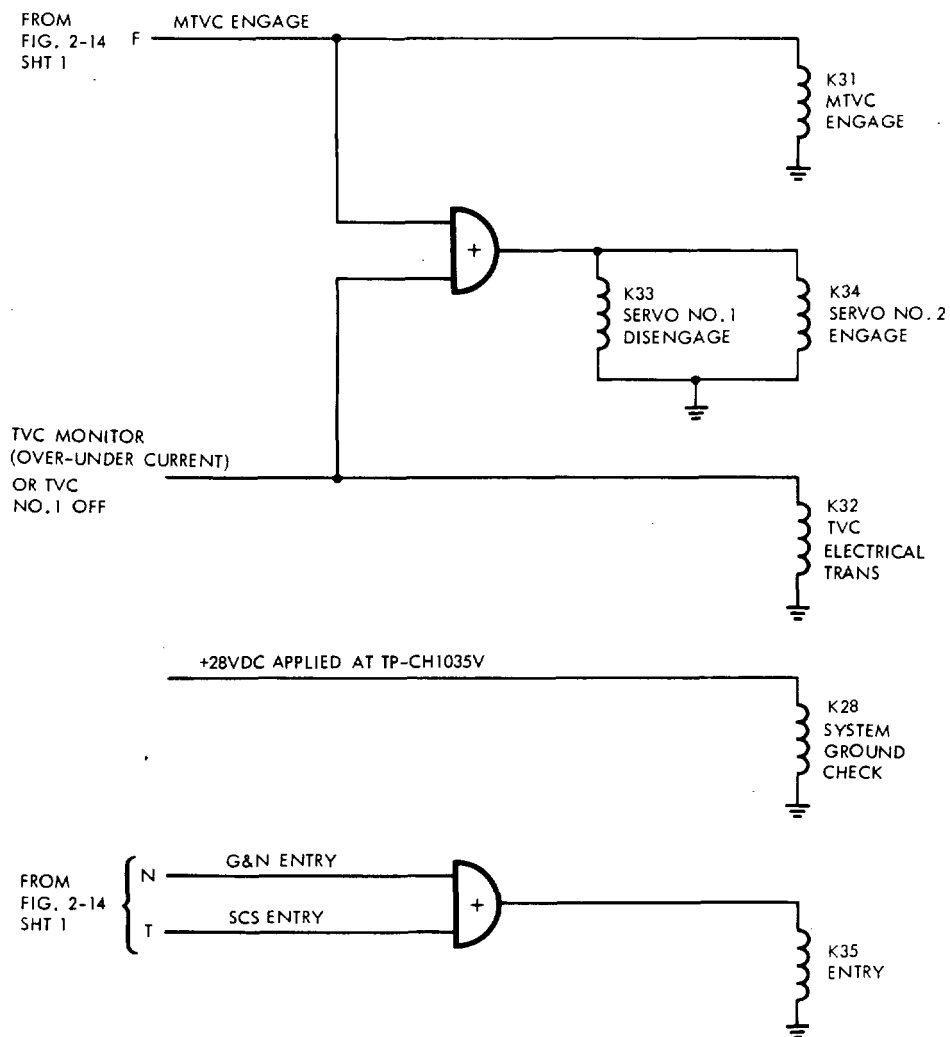
Mission \_\_\_\_\_ Basic Date 12 Nov 1966 Change Date \_\_\_\_\_ Page 2-3.23/2.3-24

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SCS

NOTE: See Fig. 2-13 Sht 5 for relays K36, K37, & K38.

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Figure 2.3-5. SCS Switching Logic (Sheet 4 of 4)

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Inertial reference data may also be received by the astronauts via the MSFN voice link for AGC updating and/or for IMU alignment. With the computer subsystem in the G&N loop, automatic maneuvers and/or G&N-controlled velocity changes are possible.

The FDAI receives total attitude and attitude error information from the G&N system. The FDAI indicates S/C total attitude (S/C reference attitude) and attitude error. Total attitude represents the gimbal angles of the IMU; and attitude error is the difference between the IMU gimbal angles and the desired attitude. The desired attitude is obtained by maneuvering the S/C either manually or automatically in the directions that null out the indicated errors. This establishes S/C attitude to the desired inertial reference. The FDAI also displays rotational rates obtained from the SCS rate gyros. The SCS rate gyros supply rate information for all G&N and SCS control and display functions.

In G&N modes, the FDAI ball is continuously controlled by signals from the IMU gimbal angle resolvers. In SCS modes, the ball is controlled by the AGCU total angle resolvers. AGCU signals are applied to the ball only during manually initiated attitude changes (assuming none of the BMAGs are rate caged) and in the SCS entry mode after 0.05 G switching. At all other times, the ball remains stationary. The ball is always driven with reference to the IMU axes with the AGCU providing the conversion for the BMAGs from body axes to IMU axes.

Attitude Reference/SCS. If the IMU cannot be used for attitude reference, a backup or strapdown attitude reference comprised of assemblies contained within the SCS will provide inertial attitude reference. The strapdown reference is mechanized within the following:

- Attitude Gyro Accelerometer Assembly (AGAA)

Contains the body-mounted attitude gyros (BMAGs), X-axis accelerometer, and self-contained electronics. Provides attitude error signals for the attitude control subsystem, AGCU, and FDAI. The BMAGs are also a source for backup rate signals, if required.

- Rate Gyro Assembly (RGA)

Provides angular rate signals to the attitude control (ACS) subsystems and to the FDAI.

- Attitude Set/Gimbal Position Indicator (AS/GPI)

The AS section provides a capability to set in desired reference attitudes and align the ARS to those attitudes. The GPI section allows the astronauts to manually position the SPS engine gimbals to a trim position prior to a delta V maneuver.

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- Display/Attitude Gyro Accelerometer Assembly Electronic Control Assembly (D/AGAAECA)

AGAA section: Contains electronics required to operate the BMAGS and to interface with the AGCU

DECA section: Provides the interface electronics between all sensors and corresponding displays

- Auxiliary Electronic Control Assembly (AECA)

AGCU section: Performs the mathematical computations and contains the transformation matrices required to display attitude and attitude errors of the S/C. The AGCU is the primary control device for the SCS ARS.

The remainder of the AECA contains circuitry for the SPS engine thrust ON/OFF control function.

- Flight Director Attitude Indicator (FDAI)

The FDAI (figure 2.3-12) provides the visual displays for S/C attitude; included is total attitude readout (FDAI ball) gimbaled in three axes: roll, pitch, and yaw.

Pitch and yaw total attitude is read from either the body axes index ( $\nu$ ) or the navigation axes index ( $\oplus$ ). The indices are fixed to the instrument faceplate. Roll is indicated by a roll bug (indicator needle driven by the roll gimbal through a gear mechanism). Roll attitude is read by comparing the roll bug position with reference to a scaled bezel ring about the instrument periphery.

Attitude errors are indicated by three fly-to needles.

Angular rates are indicated by three fly-to needles.

A + roll rate or + roll error will cause those needles to deflect left.

A - roll rate or - roll error will cause the needles to deflect right.

A + pitch rate or + pitch error will cause those needles to deflect down. A - pitch rate or - pitch error will cause the needles to deflect up.

The yaw rate and error needles deflect in the same directions as the roll needles.

To correct the error, the S/C is automatically or manually rotated in the direction of needle deflection.

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The SCS attitude reference subsystem is mechanized such that it is used primarily for monitoring S/C attitude. Consequently, automatic maneuvering is not possible when SCS modes of operation are selected. However, by using the FDAI as a monitor and by proper selection of controls, precision manual maneuvers can be performed.

The subsystem, acting as a strapdown reference, will supply all of the attitude data normally available from the IMU. These data are subsequently applied to the FDAI for presentation of S/C attitude. The IMU is a three-gimbal platform and therefore will achieve a gimbal lock condition. The middle and outer gimbals become parallel and the output is not predictable. The AGCU has a similar function which creates an effective gimbal lock. This occurs in both systems for a 90-degree yaw displacement with respect to the navigation base. The FDAI and yaw attitude set control provides markings that will serve as a warning prior to achieving a gimbal-lock condition.

Basically, the body-mounted attitude gyros (BMAGS), attitude gyro coupling unit (AGCU), and the FDAI are the primary inertial sensing, computing, and display elements of the strapdown system. Attitude errors in roll, pitch, and yaw body axes are sensed by the body-mounted attitude gyros. The error signals are conditioned and subsequently directed to the FDAI for display of total attitude and attitude error. The major part of the conditioning takes place in the AGCU which provides signal inputs to the FDAI comparable to that of the IMU.

The AGCU section of the auxiliary electronic control assembly is the primary control or computing device for the SCS attitude reference subsystem. It performs most of the inertial reference computations and performs the mathematical conversions and transformations required to display total attitude and attitude error. The attitude gyro torquing loop, that the AGCU electromechanical elements are a part of, perform the following:

- Generate a pulse train that is equivalent to the total change in S/C attitude
- Provide two-directional control of resolver shaft angles
- Provide torquing current for the attitude gyros
- Provide forward and reverse conversion of gyro and attitude set error signals to appropriate axes representation for FDAI display, and for gyro torquing.

The SCS rate gyros sense vehicle angular velocity, and supply angular rate signals to the system for rate stabilization and to the FDAI rate indicators. The proper selection of switches will place the BMAGS in a backup-rate condition, and provide rate signals to the FDAI rate indicators. Whenever manual thrust vector control is selected, the BMAGS will automatically be placed in the backup-rate condition.

Attitude Reference Control. After a maneuver or a series of maneuvers, the S/C attitude (body axes) is, each time, different with respect to the inertial reference frame. Therefore, the requirement exists for a method of resolving the rotations about the different body axes, and

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establish a relationship between the body axes and the axes of the fixed reference frame. This relationship is established through an Euler angle transformation process obtained from either the IMU (stable element) or the strapdown attitude reference subsystem. The Euler angle, then, is the resolved difference between the S/C body axes coordinates and the coordinates of the fixed inertial reference. The Euler angle attitude of the S/C, as displayed on the FDAI, is with respect to the coordinates of the fixed reference frame.

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The conversion from body axes to Euler angle readout on the FDAI, basically, consists of a forward transformation and a reverse transformation. (See figure 2.3-3.) The forward transformation is essentially body-to-navigation axes conversion, then navigation axes-to-Euler angle transformation by resolvers in the AGCU. The resolvers and gimbal servos in the FDAI position the total attitude displays, resulting from the Euler errors. The reverse transformation is essentially Euler angle-to-navigation axes transformation by resolvers in the AGCU, then navigation-to-body axes conversion for signal application to the attitude gyro torquing amplifiers. After amplification, the signals are demodulated and applied to the gyro torquing coils which torque the gyros to null the original error.

After initial alignment to the IMU reference, the BMAG/AGCU loop is opened by relay action and further positioning of the FDAI ball is prevented. However, if the rotation control, for example, is displaced, the loop will be closed and the FDAI ball will follow S/C motion until the control is neutralized. The BMAG/AGCU loop will open and the ball will again be stationary. If in G&N mode, the FDAI ball is always coupled to represent and follow IMU gimbal angles.

Attitude Errors. The FDAI attitude error indicators represent the difference between actual S/C attitude and the inertial reference. The error is referenced to the S/C body axes in all modes of operation, except for G&N entry mode.

Signals that position the attitude error indicator of the FDAI come from three possible sources. (See figures 2.3-3 and 2.3-4.) In SCS modes, either the BMAGS or the AGCU provide body axes error signals to the error indicator meter movements. AGCU signals are applied when ATT SET is selected on the attitude set section of the AS/GPI. This applies the body axes equivalent of the difference between the attitude set resolver shaft and the AGCU resolver shaft.

When ATT SET is not selected, the outputs of the three BMAGS are applied to the attitude error meter movements of the FDAI. Whether from the BMAGS or the AGCU, the error signals are directed to the meter

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movements through scaling, range adjust, demodulator, and amplifier circuits. The following chart provides mode versus full-scale error indications as read on the FDAI.

Mode	Roll	Pitch	Yaw
Monitor	$\pm 25^\circ$	$\pm 15^\circ$	$\pm 15^\circ$
SCS and G&N Entry	$\pm 25^\circ$	$\pm 5^\circ$	$\pm 5^\circ$
All other modes	$\pm 5^\circ$	$\pm 5^\circ$	$\pm 5^\circ$

When G&N modes are selected, the error signals are directed to the FDAI via the inertial coupling display units (CDUs) and the attitude reference conversion circuitry. The roll and yaw channel signals are referenced to either the navigation base axes or the S/C body axes. Conversion in the pitch channel is not required. The capability to reference the roll and yaw channel signals to either the navigation base or S/C body axes is required to facilitate roll and yaw channel cross-coupling control. This is required when G&N entry maneuvers are performed; in which case, reference is to the navigation base axes.

Rates. The following chart provides mode versus full-scale rate indications as read on the FDAI.

Modes	Roll	Pitch	Yaw
Monitor SCS Entry G&N Entry	$\pm 25^\circ/\text{sec}$	$\pm 5^\circ/\text{sec}$	$\pm 5^\circ/\text{sec}$
SCS LCL Vert or SCS ATT Cont or G&N ATT Cont	$\pm 1^\circ/\text{sec}$	$\pm 1^\circ/\text{sec}$	$\pm 1^\circ/\text{sec}$
SCS and G&N V	$\pm 5^\circ/\text{sec}$	$\pm 5^\circ/\text{sec}$	$\pm 5^\circ/\text{sec}$

SCS Attitude Reference Alignment. Alignment of the attitude reference subsystem is performed by comparing the outputs of the total attitude set resolvers in the AGCU with the attitude set resolvers of the AS/GPI. The attitude set resolver shaft can be positioned by using the attitude set dials (thumbwheels) on the front of the AS/GPI. The dials indicate Euler angle of the attitude set resolver shaft, and the output of the resolver is the Euler angle difference between the attitude set resolvers and the total attitude resolvers in the AGCU.

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When the FDAI ALIGN switch on the AS/GPI panel is pressed, the AGCU resolvers will align to the attitude set resolvers. Euler-to-navigation axes transformation, and navigation axes-to-body axes conversion takes place for the FDAI attitude error display functions. In SCS control modes, the attitudes indicated on the attitude set dials will be indicated on the FDAI with respect to the navigation axes symbol and the roll index.

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2.3.2.3.2 Attitude Control Subsystem.

The attitude control subsystem (ACS) (figures 2.3-4 and 2.3-5), essentially, provides the means for controlling spacecraft motion. Control is either manual or automatic when using controlled inputs from the G&N system. Spacecraft motion, other than drift, is initiated through the use of the S/M RCS jets prior to C/M-S/M separation. After separation (entry), the C/M RCS jets are used. An attitude control logic chart is presented in figure 2.3-6.

There are four types of controls that the ACS contends with which to satisfy mission requirements. (See figures 2.3-4 and 2.3-7.) These are rotation, translation, attitude hold, and rate damping only. Rotational motion is required to establish navigational sightings with the G&N optics subsystem telescope and sextant for S/C alignment prior to a velocity change for TVC functions, for antenna orientation, for T/C transmission and reception, and for lift vector control (roll control plus pitch and yaw rate stabilization) during entry.

Translation control for the AS204A mission is required for the ullage function prior to SPS engine ignition.

Holding attitude (attitude hold) to a fixed reference (established by the ARS) is necessary for navigational sightings, preparing for a velocity change and ullage maneuvers. After establishing attitude hold, the S/C motion involved is the amount of drift that the S/C is allowed to rotate about its axes. The drift is limited to a selectable minimum or maximum deadband about all three axes.

Rate damping only provides rate stabilization during entry or in the event of an abort prior to launch escape system (LES) jettison. The motions involved here are the finite firings of the RCS jets when rotational rates exceed certain limits. The RCS jet firings will decrease the rates to within predetermined limits. The rates are limited to 0.2 degree/sec for all modes, except SCS and G&N entry modes when the rates are increased to 2 degrees/second.

The ACS includes the roll, pitch, and yaw electronic control assemblies (ECAs), the delta V indicator, attitude impulse section of the G&N optics control panel and, in addition, utilizes all of the physical elements and functions of the attitude reference subsystem.

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ROLL QUAD & C/M SYSTEM		S/M RCS ENGINES																C/M RCS ENGINES											
		QUAD A				QUAD B				QUAD C				QUAD D				SYSTEM A						SYSTEM B					
ENGINE NO.		2	3	13	16	7	6	9	12	1	4	14	15	8	5	10	11	1	2	5	8	9	12	3	4	6	7	10	11
ROTATION	PITCH UP		•							•								•						•					
	PITCH DOWN	•									•								•						•				
	YAW RIGHT					•									•				•							•			
	YAW LEFT						•								•					•						•			
	ROLL RIGHT		•					•				•			•		•			•						•			•
	ROLL LEFT			•					•				•				•				•					•			•
TRANSLATION	+X	•				•				•					•														
	-X		•				•				•				•														
	+Y			•							•				•														
	-Y				•							•				•													
	+Z							•								•													
	-Z								•								•												
SCS CIRCUIT BREAKERS *		MN A	MN B	MN A	MN B	MN A	MN B	MN A	MN B	MN A	MN B	MN A	MN B	MN A	MN B	MN A	MN B	MN A	MN B	MN A	MN B	MN A	MN B	MN A	MN B	MN A	MN B	MN A	MN B
SCS CHANNEL PITCH AND YAW SWITCHES		PITCH	A&C ROLL	YAW	B&D ROLL	PITCH	A&C ROLL	YAW	B&D ROLL	PITCH	A&C ROLL	YAW	B&D ROLL	PITCH	A&C ROLL	YAW	B&D ROLL	PITCH	YAW	B&D ROLL	PITCH	YAW	B&D ROLL	PITCH	YAW	B&D ROLL	PITCH	YAW	B&D ROLL

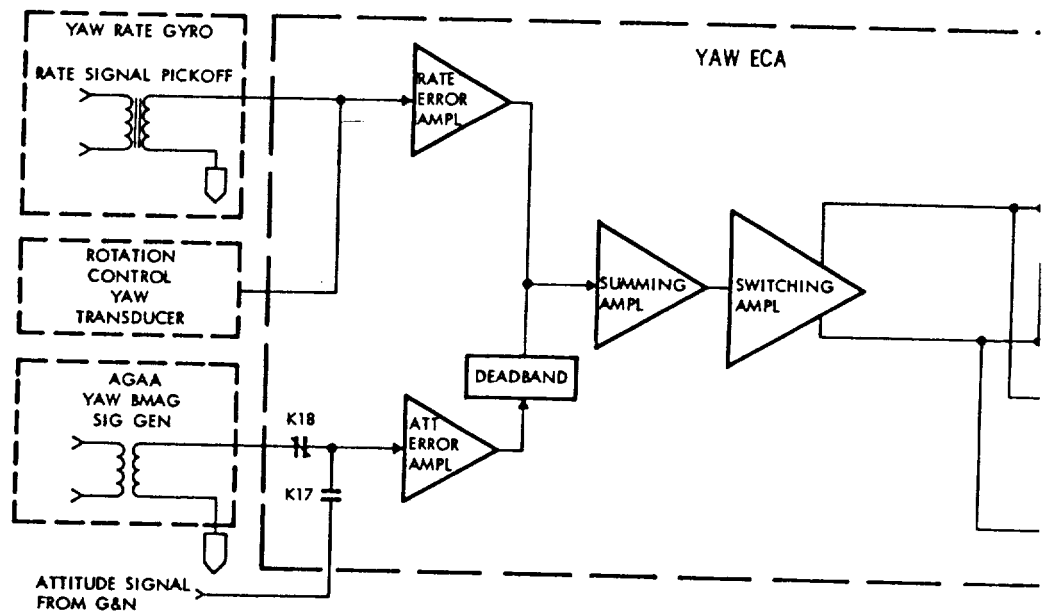
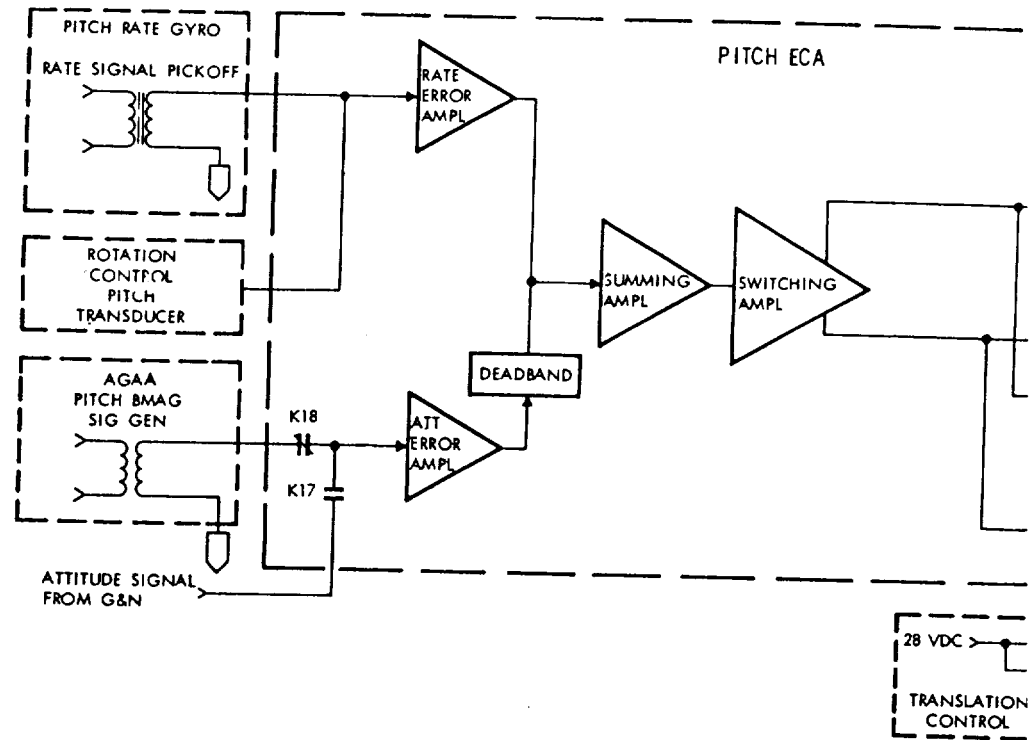
\* CIRCUIT BREAKER TABULATION IS APPLICABLE TO RCS ENGINES AUTOMATIC COIL OPERATION ONLY. FOR MANUAL DIRECT COIL OPERATION, POWER IS APPLIED FROM SCS DIRECT CONT CIRCUIT BREAKERS MN A OR MN B BY ACTUATION OF THE PILOTS OR CO-PILOTS HAND CONTROLLER, RESPECTIVELY.

- NOTES: 1. Combinations of translation and rotation maneuvers requiring the simultaneous firing of identical S/M RCS engines is prohibited by jet selection logic circuit design.
2. Minimum impulse operation is accomplished in the roll axis by two engines only. Remaining engines are disabled by setting the A&C ROLL CHANNEL switch to OFF and pulling one B&D ROLL circuit breaker; or setting the B&D ROLL CHANNEL switch to OFF and pulling one A&C ROLL circuit breaker.
3. Fuel conservation and/or consumption balance between quads may be accomplished by using applicable SCS CHANNEL switches and circuit breakers to select single-engine operation in each direction.

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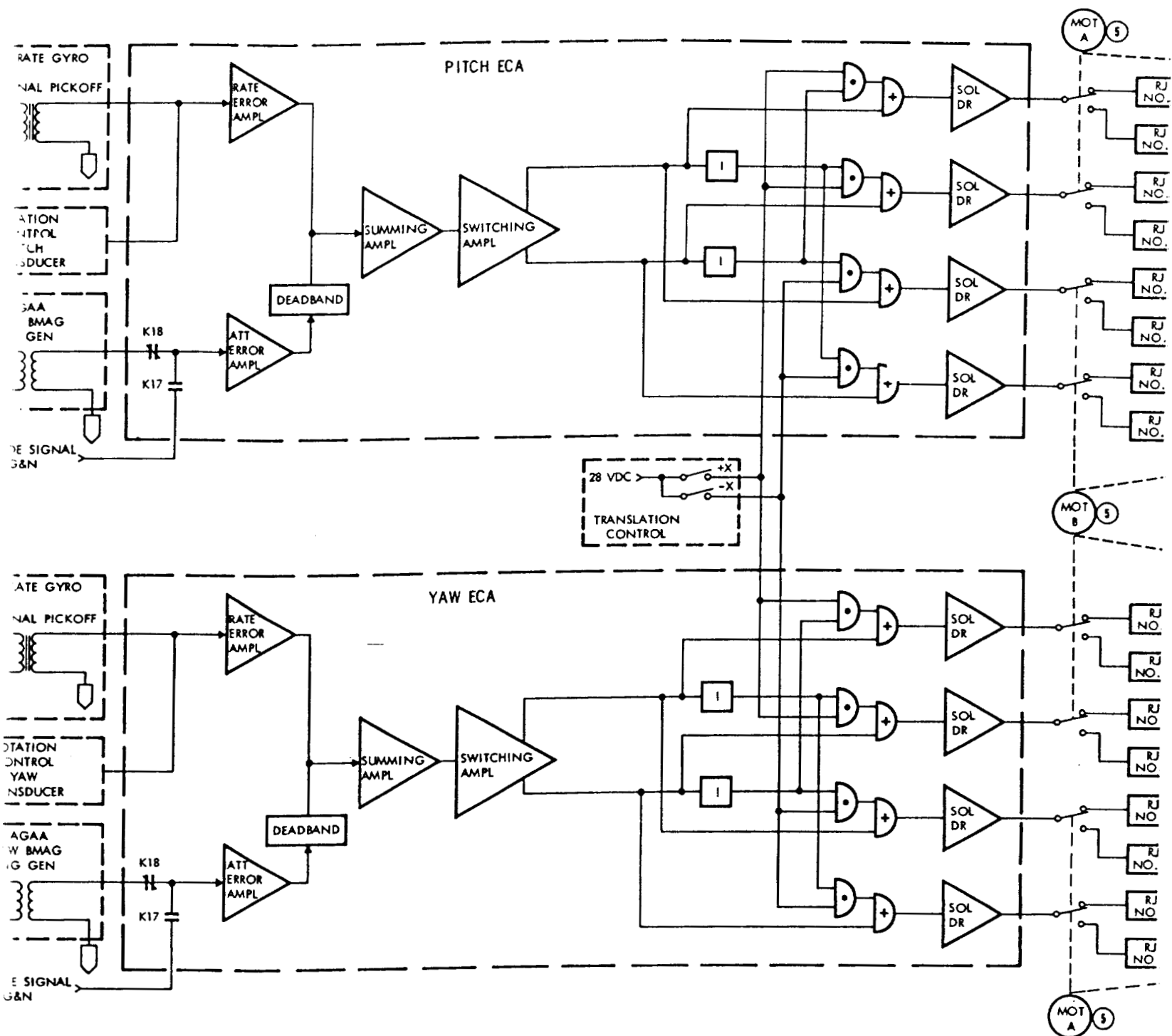
Figure 2.3-6. SCS Attitude Control Logic Chart

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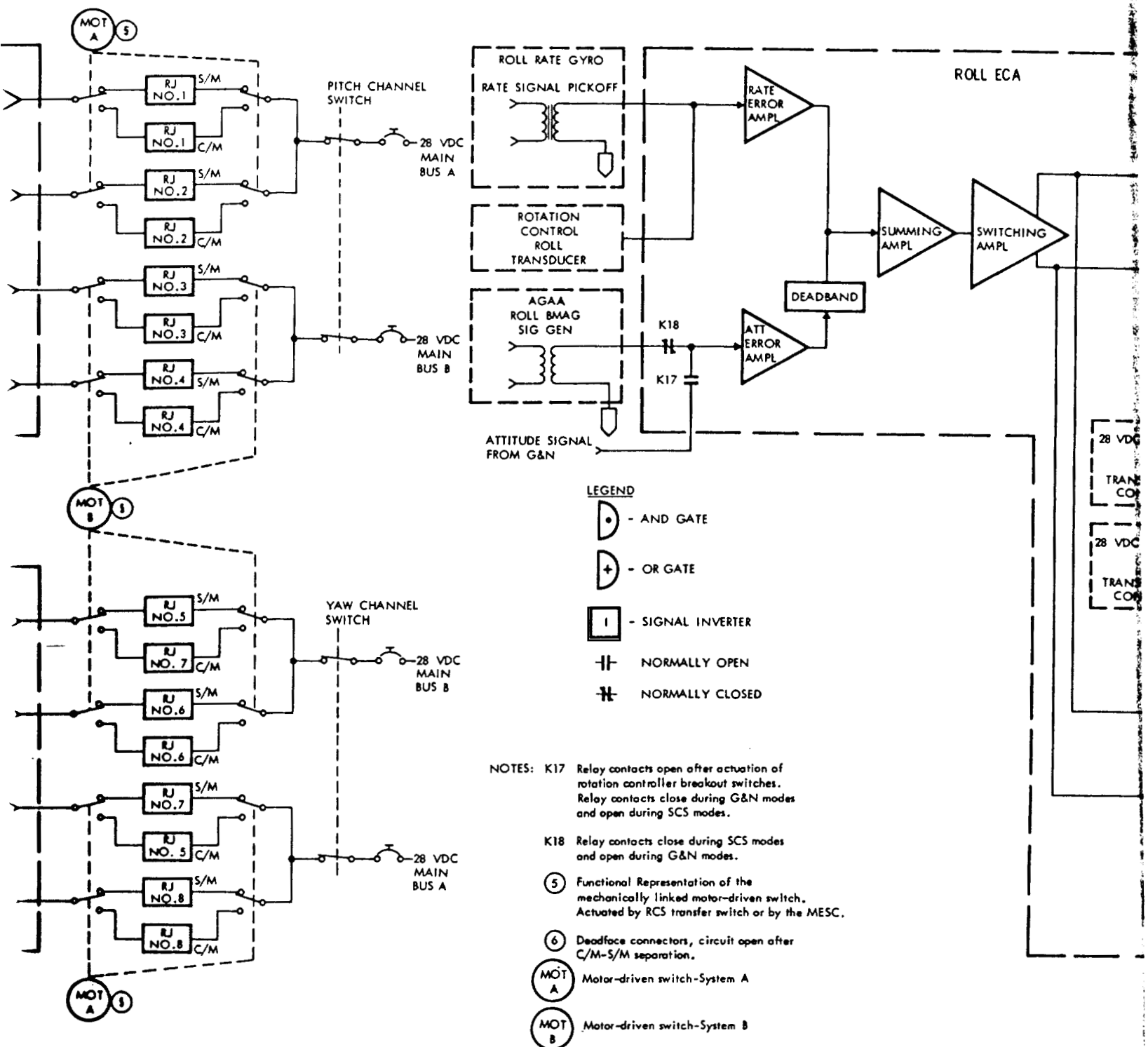
FOLDOUT FRAME /





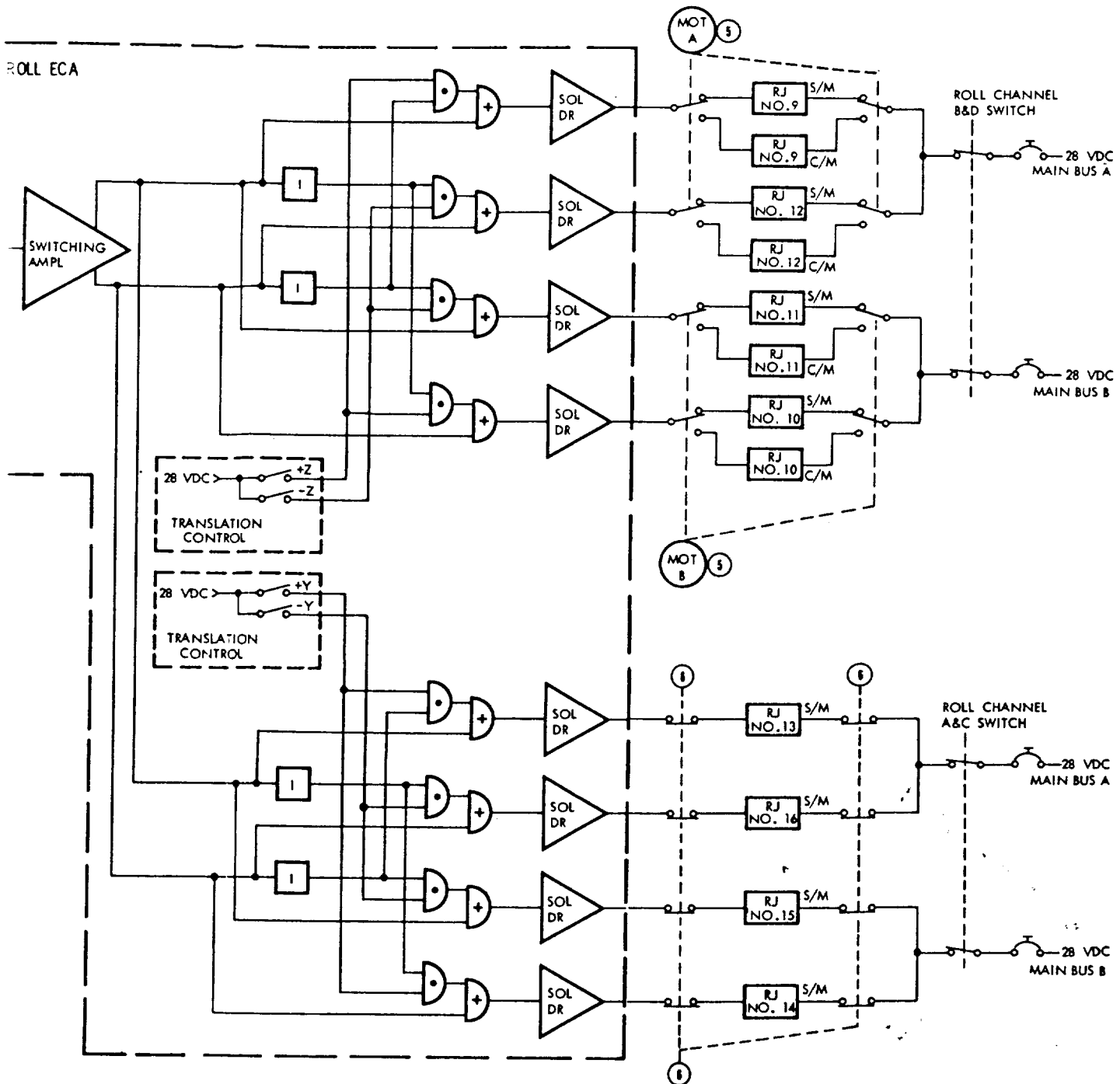








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Figure 2.3-7. Jet Selection Logic Functional Flow Diagram

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The attitude control subsystem electronics is contained within the roll, pitch, and yaw ECAs. The ECAs accept the manual and automatic inputs, conditions them, and directs on-off electrical command signals through jet selection logic to appropriate automatic (normal) coils of the RCS jets. The output of the jet selection logic will be either a time-modulated signal or a steady-state +20-vdc signal.

SCS

There are basically two types of inputs to the attitude control subsystem: manual and inertial sensor (AGAA, RGA, IMU). Manual inputs are provided by the rotation and translation controls, switches on the SCS control panel, attitude impulse switch on the attitude impulse section of the G&N optics control panel, and the direct ullage switch on the delta V display panel. These controls can be used for manual ullage maneuvers or as a backup during automatic delta V functions. The attitude impulse switch commands inputs to the ACS and subsequently to the RCS jets for small angular accelerations.

The inertial sensor inputs are provided by the AGAA, RGA, and the IMU via the G&N system. The AGAA (BMAG) and rate gyros (RGA) inputs are used for attitude hold, rate stabilization, and manual rotation control. The IMU inputs provide G&N attitude hold and command rate signals for manual or automatic rotational maneuvers.

Rotation Maneuvers. Rotation maneuvers can be performed by using four different types of manual controls or automatically by using the G&N computer subsystem. Manual rotation maneuvers are accomplished by using the rotation control, commonly called control stick steering (CSS), direct or emergency control which is a function of the rotation control, attitude impulse control, and positioning of the inertial CDUs. Automatic maneuvers result from astronaut inputs to the AGC via the DSKY. The AGC, according to computer program, automatically positions the CDUs and will command S/C motion to the programmed attitude.

Normal CSS is a proportional manual function and is available at any time in all operational modes. The maximum CSS proportional rates that can be commanded are as follows:

- 19 degrees per second (roll axis) entry mode
- 5 degrees per second (pitch and yaw axes) entry mode
- 0.79 degree per second (all axes) all other modes.

Even though CSS commands greater rates, the SCS electronics will limit the rates to those values given. Proportional control is obtained by using the rate gyro output to cancel the output of a transducer within the rotation control. CSS proportional commands are always directed to the automatic solenoid coils of the RCS engines.

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When the rotation control (stick) is displaced, a transducer within the stick will command a rotation proportional to the amount of stick displacement. The rotational rates are limited to predetermined values, depending on the operational mode.

When in SCS attitude control mode and as the stick is displaced approximately 2.5 degrees from neutral, breakout switches within the stick close causing the BMAG and the AGCU to become closed loop. It also inhibits BMAG error signals to the SCS electronics. As the S/C rotates, the AGCU applies torquing current to the BMAG torquer coils. The gyros, then, are torqued at a rate proportional to the magnitude of BMAG error, keeping attitude error at approximately zero. Thus, the AGCU will follow S/C motion and establish a new attitude reference when the stick is returned to neutral.

When in G&N attitude control mode, a G&N SYNC switch must be energized to enable the attitude hold function when the control stick is returned to neutral. The G&N sync function provides IMU/CDU closed loop operation which keeps attitude errors at approximately zero during the maneuver. Consequently, the S/C will hold the new attitude when the stick is returned to neutral. If G&N sync is not enabled, the S/C will return to the attitude established before stick displacement.

NOTE For the AS204A mission the G&N SYNC switch will remain OFF for the entire mission.

The computer program will control the actual maneuver rate, but the SCS will limit the maximum. The maximum non-entry maneuver rate is 10°/second and entry maneuver rate is 17°/second in all axes.

Direct rotation control is a nonproportional function whereby initiated commands are applied directly to the RCS direct coils. To accomplish direct rotation, the DIRECT RCS/OFF switch (MDC-8) is set to DIRECT RCS; the SCS-CHANNEL switches (MDC-8) are set to OFF; if high rates are to be maintained, and the control stick is rotated about the desired axis or axes to hardstops. Just prior to engaging the hardstops, a switch closes and applies a direct command to the RCS direct coils. Rate feedback is not used to cancel stick movement. The breakout switches, however, close the BMAG/AGCU loop, and attitude error output to the SCS electronics is inhibited. With proper control and switch configuration, direct control is available at any time.

The attitude impulse control (G&N optics control panel) provides the capability for commanding low-rotational rates about all three axes. Attitude impulse control is available only in SCS or G&N attitude control modes and is used primarily for precise attitude maneuvers during navigational or star sighting periods. After the control is enabled and displaced, a switch closure in the control and an RC network combination generate one

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pulse, which is applied to the RCS jet selection logic. One pulse is generated for each attitude impulse switch closure (control displacement). It is not a proportional control and attitude hold is not available when the control is returned to neutral. When the control is enabled, relay action removes all rate, attitude error, and rotation control inputs to the SCS electronics.

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Automatic positioning of the CDUs is accomplished by using the DSKY. This method of control is primarily used during G&N entry.

Translation Maneuvers. There are three methods of initiating translation maneuvers: normal translations, using the translation control; direct ullage, using the direct ullage button on the delta V control panel; and separation ullage, using the translation control.

Translation commands are not proportional; operation is through switch closure only and is available during all modes of operation prior to C/M-S/M separation. During normal translation, switch closures within the translation control provide commands to the jet selection logic which fire the appropriate jets for the desired direction of translation. The commands are directed to the automatic RCS engine coils. A primary function of normal translation is the ullage maneuver, which is necessary in preparation for a velocity change. Ullage maneuvers require translation along the +X-axis.

Direct ullage is accomplished by using the DIRECT ULLAGE pushbutton on the delta V control panel. When pressed, switch closures command the appropriate direct RCS coils to initiate translation along the +X-axis. Direct ullage is available at any time prior to C/M-S/M separation. Upon C/M-S/M separation, the direct ullage function to the C/M pitch and yaw direct coils is inhibited by deadfacing. It is primarily a backup operation in the event of normal translation failure. Ullage will continue as long as the DIRECT ULLAGE pushbutton is pressed.

The separation ullage function requires a CCW rotation of the translation control into a detent position. Ullage commands are directed to the direct RCS coils. The separation ullage maneuver is performed when SPS aborts are necessary or when S-IVB separation is required. If the LES has been jettisoned, the signal from the translation control in CCW detent will command the sequential events control system (SECS) to sequence the separation ullage and consequent separation from the S-IVB. If the LES is attached to the S/C, the same command will initiate a LES abort.

In G&N and SCS modes, a clockwise rotation of the translation control into a detent generates a CSS logic signal that inhibits attitude gyro signals from the SCS electronics, and provides BMAG/AGCU closed loop operation. It also initiates manual thrust vector control (MTVC).

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The CW rotation enables capability for manual roll control by the rotation controller during G&N entry. This is normally an automatic function of the G&N system and entry program.

Attitude Hold. Attitude hold is a capability of the ACS to hold S/C attitude within selected deadband limits of a fixed reference attitude. The deadband (amount S/C is allowed to drift either side of reference attitude) is selected by setting the ATT DEADBAND switch on MDC8 to either MAX or MIN. In the G&N or SCS entry modes, however, the deadband will be maximum regardless of deadband switch position.

The ACS accomplishes attitude hold by inputting summed attitude error and rate gyro signals to the jet selection logic, which will turn on appropriate jets to keep the S/C within the selected deadband. The attitude error signal is conditioned by a deadband circuit and rate limiter before it is summed at the input of a summing amplifier with the rate gyro signal. When the summed input to the amplifier is greater than its threshold, the amplifier will cause a switching amplifier to pulse the jet selection logic. The lower the angular rates, the closer the S/C is allowed to drift to the deadband limits. As angular rates increase, the summed error/rate signal increases in magnitude proportionate to time. Therefore, the sooner the threshold of the summing amplifier is reached, the sooner the jets will fire, damping the oscillation.

A limit cycle switch on MDC8 can be used to provide time modulated pulses to the jet selection logic. Limit cycle is primarily used for fuel conservation purposes. The limit cycle switch enables a psuedo rate feedback circuit at the output of the switching amplifier previously discussed. The psuedo rate, and consequently the time-modulated pulses, is a function of signal magnitude at the switching amplifier input. For large signal inputs, the output pulses will cause the RCS jets to pulse at a higher frequency and for longer periods. As the error decreases, the pulse widths and frequency decrease proportionately until the error is nulled.

The psuedo rate loop is normally used at all times (limit cycle on) when an inertial attitude is being maintained.

Attitude hold is available at all times in three axes, except during monitor mode and SCS entry mode after the 0.05 G switching. During G&N entry after 0.05 G switching, roll attitude hold is still enabled. Yaw and pitch attitude hold is inhibited.

Rate Damping Only. In addition to attitude control and maneuvering capabilities, the ACS provides a rate damping only capability. Although rate damping is a normal function during attitude control modes, rate damping can be used to limit S/C rotational rates (rate stabilization) when attitude hold is not being used. Normally, when S/C rotational rates exceed 0.2 degree per second in any axis, the rate gyros or the BMAG in

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backup rate sense the angular accelerations. The signals, conditioned via the roll, pitch, and yaw ECAs and through jet selection logic, are applied to applicable RCS engines to keep the S/C rates within the 0.2-degree-per-second rate deadband. If in SCS or G&N entry mode, the rate deadband is increased to 2 degrees per second. Rate stabilization, in addition to the attitude control functions, is available when any of the following conditions exist:

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- Selection of monitor mode after S-IVB separation
- Selection of monitor mode for LES aborts
- Clockwise rotation of translation control after S-IVB separation
- SCS entry mode after 0.05 G switching
- G&N entry mode after 0.05 G switching (pitch and yaw axes only).

2.3.2.3.3 Thrust Vector Control Subsystem.

The purpose of the thrust vector control (TVC) subsystem (figures 2.3-4 and 2.3-5) is to align or position the gimbaled SPS engine to a trim position prior to SPS thrusting and maintain this trim during the acceleration period. The S/C experiences a changing center of gravity (c. g.) caused by the consumption of fuel and oxidizer during acceleration. The TVC subsystem maintains the SPS engine thrust vector through the c. g. and holds S/C attitude so that the thrust vector will remain in the desired direction. This compensates for undesirable forces that affect S/C stability because of the shifting c. g. Thrust vector control, in addition to the TVC subsystem, utilizes the functions of the G&N system, the propulsion systems, and the SCS attitude reference and attitude control subsystems.

The TVC subsystem essentially controls the SPS engine gimbals, and consequently the thrust vector, by energizing the gimbal actuators; one for pitch and one for yaw.

The normal method for controlling thrust is through the G&N delta V mode. This provides the most accurate control. The accelerometers on the IMU stable element and the AGC provide steering commands to the SPS engine gimbals and continuous trajectory corrections to compensate for undesired accelerations. The AGC also compensates for the near-body orbital and gravity affects on the S/C. So, the actual versus required velocity change will result in a curved trajectory.

Normally, both G&N delta V and SCS delta V modes operate by driving No. 1 and No. 2 servo electronics. If a failure occurs in No. 1, an automatic switchover to drive No. 2 servo electronics and No. 2 gimbal motor will occur. Or, No. 2 will drive if No. 1 is switched off or if manual thrust vector control is initiated.

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A manual method of thrust vector control is provided to control the position of the SPS engine gimbal. When operating manually, inputs from the rotation control, translation control, and the BMAGs are directed to redundant servo electronics No. 2 and the No. 2 gimbal actuator motor. The nominal authority from either rotation controller is  $\pm 6$  degrees of SPS gimbal engine deflection.

The gimbal position display section of the AS/GPI panel, the delta V display, SCS control panel, rotation control, translation control, and the SPS switches on MDC-3 are the principle controls and displays associated with TVC. They provide the capability for control and monitoring of system performance.

Thrust Vector Control. When G&N delta V mode is selected, automatic thrust on-off, attitude, and steering commands initiate in the G&N system. However, before the ullage maneuver and thrust-on, the gimbal position trim control thumbwheels on the AS/GPI are used to position the engine gimbals. The engine position is verified on the AS/GPI visual display. The gimbals are aligned such that, at the moment of thrust-on, the thrust vector will be through the S/C c. g. This is necessary before any delta V to prevent undesirable rotational movements about the c. g. when thrusting begins.

In addition to initial positioning of the gimbals, the amount of acceleration required for the velocity change less tailoff is set into the delta V remaining counter on the delta V display. This allows the crew a method of monitoring delta V remaining and, when in SCS  $\Delta V$  mode, provides automatic thrust-off capability. A coincidence switch in the delta V display will, by inhibiting the thrust on logic, automatically terminate thrust when the  $\Delta V$  remaining counter indicates zero. The accelerometer in the AGAA senses +X acceleration, and supplies acceleration signals to timing and output logic which subsequently drives the delta V remaining potentiometer to zero. The accelerometer threshold is  $1 \times 10^{-4}$  g, but the  $\Delta V$  counter will only step once for each 0.25 t/sec velocity change.

NOTE It is possible, but not recommended, to have SPS engine ignition without ullaging when in SCS  $\Delta V$  mode.

Prior to SPS ignition, the G&N system inputs attitude error information to the ACS to hold the S/C at a constant attitude in all three axes. Attitude errors from the G&N system and rate information from the SCS rate gyros are also applied to the SPS gimbal servo loops. Upon engine ignition, the combined attitude error and rate gyro inputs, conditioned by the servo electronics, reposition the gimbals as necessary to rotate the S/C to compensate for c. g. shift. The gimbal position is also modified by steering commands from the AGC so that the thrust vector will point in the right direction for the curved trajectory.

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The BMAG/AGCU loop remains open and follows IMU changes so that the SCS will have the same inertial reference in the event a switchover to SCS delta V mode is necessary.

Normally, G&N delta V mode utilizes the primary gimbal servo and actuator motor No. 1. If the gimbal motor switches on MDC-3 are activated, a TVC monitor signal generator (over-undercurrent sensor) in the actuator will sense a failure of motor No. 1. If motor No. 1 fails, the sensor will automatically cause a switchover to motor No. 2 in the actuator. Since the No. 2 servo electronics are driven simultaneously with No. 1, an interruption during the velocity change will not occur. Motor No. 2 also contains a TVC monitor signal generator, but is not used. In the event of motor No. 2 failure, causing an excessive current drain on the d-c bus, a 70-ampere circuit breaker in the line will disconnect the motor from the d-c supply bus. Motor No. 2 has no switchover or warning light capability.

In SCS delta V mode, the gimbal servo loops function the same as in G&N delta V mode. Attitude error information, however, is derived from the BMAGS. The rate loop is identical, unless in backup rate condition. SCS delta V will not function if the BMAGS are required for backup rate because of the loss of attitude error information.

SCS delta V keeps the thrust vector through the c. g. by first comparing the trim position commands set by the gimbal position thumbwheels and the position transducer feedback signals. The difference, combined with attitude error information from the BMAGs, conditions the servo electronics to energize the actuator clutches.

Except for mode selection and thrust-on requirements, the same prerequisites for thrust-on, and the control and display functions are the same as for G&N delta V. The SCS system does not provide automatic thrust-on. A thrust-on switch on the delta V display provides the thrust-on command for SCS delta V mode. Thrust-off, however, is automatic by closing of the coincidence switch. A NORMAL-OFF-DIRECT-ON switch on the delta V display is also provided for manual thrust-on and serves as a manual backup for all automatic thrust-off commands.

If the translation controller cannot be used for the ullage maneuver prior to thrust-on, a DIRECT ULLAGE switch on the delta V display provides a manual backup to initiate ullage.

A manual delta V can be performed, providing a delta V mode has been selected and the translation control is rotated CW into detent. This removes all normal inputs into the TVC servo loops, allows commanded inputs from the rotation control, and rate data from the BMAGs in backup-rate condition, into the redundant No. 2 servo electronics and motor No. 2 of the gimbal actuators. This provides rate-stabilized manual control of the thrust vector. Thrust-on is initiated by the momentary thrust-on switch located on the delta V display.

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The rotation control must be held to a given displacement to control the gimbals about the initial trim position established by the settings of the AS/GPI. The GPI provides the only indication of the position of the gimbal angles with respect to the S/C body axes.

2.3.3 FLIGHT CONTROL PROFILES.

There are three basic flight control profiles associated with mission AS204A. These include powered flight, coasting flight, and entry. Within these profiles, various modes of operation are established either within the atmosphere or in earth orbital environment. Because of the division of powered flight, i. e., ascent and earth orbital environment, the description is divided as follows:

- Ascent (including aborts)
- Coasting flight (earth orbital)
- Powered flight (earth orbital)
- Entry (nonpowered atmospheric flight).

As the various operational modes are discussed, reference will be made to figures 2.3-4, 2.3-5, and 2.3-6. A typical control channel yaw is shown in figure 2.3-4, sheet 2; therefore, differences not typical to the yaw channel will be clarified.

It should be noted that relays in figures 2.3-4, 2.3-5, and 2.3-7 are not relays of the actual system by number. However, the relay nomenclature is system oriented and may be cross-referenced by using the following chart.

Fig. 2.3-4, 2.3-5, 2.3-7 Relays	Function	SCS System Relay
K1	ORBIT RATE	24A14K3
K2	FDAI ALIGN	24A14K1
		24A14K2
K3	G&N ROLL, PITCH, YAW ATT SIN AND COS	22A16A3K4
		22A16A3K6
		22A17A3K4
		22A17A3K6
		22A18A3K4
		22A18A3K6
K4	AGCU CAGED	22A8K1
		22A8K2
		22A8K4
		22A8K5
K5	AGCU ALIGN	22A8K6
		22A8K7

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Fig. 2.3-4, 2.3-5, 2.3-7 Relays	Function	SCS System Relay
K6	AGCU P/Y ERROR	21A3K2
K7	R G&N ERR/AGCU INH	22A3K3
	G&NP ERR	20A3K3
	Y ERR G&N BODY	21A3K3
K8	G&NP, Y, ERR S.F.	22A20A3K1
		22A21A3K1
K9	ROLL, PITCH, YAW ERR	22A20A3K4
	AGAA	22A21A3K4
	MONITOR + G&N $\Delta V$ + G&N	22A23A3K2
	ATT CONTR + G&N ENTRY	
	+ .05G MANUAL + <span style="border: 1px solid black; padding: 0 2px;">AS</span> +	
	YAW B/U RATE	
K10	ROLL, PITCH, YAW, B/U	22A9K1
	RATE	22A9K2
		22A13K1
		22A13K2
		22A11K1
		22A11K2
K11	MTVC RT OUT	22A9K3
		22A11K3
		22A12K3
K12	ROLL, PITCH, YAW	22A23A3
	RATE	22A20A3
		22A21A3K
K13	Y/P RT SF	22A22A3
K14	R-Y RT CPLG	23A11K2
K15	RT IN TRANS	23A19K1
		23A19K1
		19A26K1
K16	ENT GAIN	23A15K1
		23A15K2
		23A17K2
K17	G&N ATT IN	23A19K2
K18	AGAA ATT IN	23A19K3
K19	D-B CHG	23A15K3
K20	RJC ATT SW	23A11K1
K21	G&N MIN IMP ENABLE	23A13K
K22	PSUEDO RT CO	23A13K
K23	RCS LATCHING RELAY	MESC Z19
	ARMED	
	(JET DVRS ENABLED)	
	SAFE	
	(JET DVRS DISABLED)	
K24	1.8 SEC LATCH	MESC Z8

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Fig. 2.3-4, 2.3-5, 2.3-7 Relays	Function	SCS System Relay
K25	MAIN DEPLOY	MESC Z12
K26	AUTO CONT INTER	23A11K3
K27	ENG IGN	23A21K2
K28	SYS GRD CK	23A21K3
K29	SCS $\Delta V$ MODE	23A21K1
K30	ENG IGN	23A27K1
K31	MTVC ENGAGE	23A18K2
K32	TVC ELEC TRANS	23A25K1
K33	SERVO NO. 1 DISENGAGE	23A14K1
K34	SERVO NO. 2 ENGAGE	23A18K1
K35	ENTRY	22A8K8
K36	$\Delta V$ INH	22A21A3K6
K38	THRUST ON LAMP	22A20A3K6

2.3.3.1 Ascent.

During the ascent phase, capability exists for monitoring boost vehicle stability. The SCS is in a monitor mode with all subsystems active, but supplies no active commands for control purposes for the first 61 seconds of flight. After 61 seconds, if aborts are required, the SCS will be used to supply signals for S/C stabilization and control.

2.3.3.1.1 Monitor Mode.

The monitor mode provides the capability of monitoring deviations from programmed launch vehicle attitude prior to S-IB separation and CSM attitude after S-IVB separation. The S-IVB utilizes a different guidance technique and monitoring C/M instruments relative to S-IVB operation provides no useful purpose. Monitor mode also provides rate stabilization, when required, any time during the mission.

Normal Ascent. At time of launch, RCS latching relays in the SECS system will be open to inhibit commands to the RCS jets. Relays K4 and K5 will be closed, providing BMAG/AGCU closed loop. The FDAI will be following IMU gimbal angle changes. The motor-driven switch 5 (figure 2.3-7) is set to the S/M position when the REACTON CONTROL SYS-TRANS C/M-S/M switch on MDC - 16 is set to S/M.

Total attitude and attitude error signals from the IMU and inertial CDU (figure 2.3-4, sheet 1) are applied to the FDAI through relays K3, K7, and K8, respectively. Attitude error signals represent deviations from the trajectory for the first stage booster only. The SCS rate gyros apply attitude rates to the SCS electronics directly and to the FDAI via relay K12.

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The X-axis accelerometer will be active, but its output will be used only if an abort delta V is required. The TVC subsystem is activated to hold the SPS engine thrust vector through the c. g. in the event of an SPS abort, and to keep the nozzle centered and stationary within the adapter. The SPS engine gimbals are aligned to null offset (pitch +0.4 degrees and yaw +3.6 degrees) prior to launch. Quiescent current on the gimbal motor clutches maintains these angles during ascent.

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LES Abort. If an LES abort is initiated (61 seconds or more after lift-off) requiring SCS operation, the SCS is enabled one second after LES ignition. The SCS is enabled by the arming of the RCS latching relays in the SECS, and the S/M-C/M transfer switch will be driven to the C/M position. The RCS latching relay will open by the operation of a barometric switch at approximately 24,000 feet during descent and will disable active commands to the C/M RCS. Besides rate stabilization, specific command inputs to the SCS above 24,000 feet will depend on altitude and other factors.

SPS Abort. An SPS abort would be initiated after the LES jettison. The translation control is rotated CCW into detent and the switch closure will cause the MESC to command a +X translation (separation ullage) via the direct coils of the S/M RCS. The direct coils are activated through the RCS transfer switch.

Before separation from the S-IVB, a delta V mode must be selected. For an SPS abort, alignment of the SPS engine gimbals is not required since they were preset prior to launch and no propellant has been consumed. At separation, an abort can be made into earth orbit or to a downrange landing site.

2.3.3.2 Coasting Flight (Earth Orbital).

The coasting flight profile ranges from a free-drift configuration (no control) to monitor mode (passive) to attitude hold (active control). The following paragraphs describe the various modes relative to the earth orbital environment.

2.3.3.2.1 G&N Attitude Control.

G&N attitude control will provide inertially stabilized attitude by utilizing the attitude reference and attitude control subsystems. Attitude data is obtained from the inertially referenced IMU. Relays K4 and K5 provide BMAG/AGCU closed loop so that if SCS attitude control is selected, the AGCU will have the same reference as the IMU for control and display purposes.

Attitude errors from the inertial CDU through relays K7 and K8 are applied to the FDAI and SCS electronics for attitude error display, and to provide attitude corrections. The errors from the CDU are the difference between the IMU gimbal angles and the commanded output of the AGC. Total attitude from the IMU is applied to the FDAI via relay K3. The

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attitude rates from the SCS rate gyro and relay K12 will drive the FDAI rate indicator at a scale range of  $\pm 1$  degree/second.

The maximum deadband limit is normally set for G&N attitude control. If navigation sightings are required, the minimum deadband may be selected. The G&N system and SCS attitude control subsystem will maintain attitude within the selected deadband limits.

Maneuvering. Automatic maneuvers may be executed by inserting commands into the AGC via the DSKY. The S/C will automatically maneuver to the computer-commanded attitude. The SCS will follow the attitude error signal inputs from the CDU in response to AGC inputs for maneuvering to the commanded attitude. Manual maneuvers can be commanded with or without attitude hold.

In G&N mode, relay K18 (figure 2.3-7) is open. Relay K17 is closed. Relay K18 inhibits BMAG inputs and allows G&N attitude error signals into the jet selection logic for the attitude hold function. When the rotation control is displaced, the breakout switches open K17, inhibiting G&N signals and allowing proportional command (rotation control plus rate gyro) signals into the jet selection logic. When the control is returned to neutral, relay K17 closes and the G&N attitude hold function is restored, provided G&N sync is active.

Translation in all axes can be commanded by the translation control. As shown in figure 2.3-5, switch closures within the control apply command signals directly to the jet selection logic and, subsequently, to the auto RCS coils. Attitude hold is a normal function when translations are initiated, using the translation control.

The direct ullage switch on the delta V display is a backup for +X translations. When this switch is activated, the signal is applied directly to the RCS direct coils. Attitude hold is not a function of direct ullage.

Attitude impulse control (panel 105, LEB) is a manual control capability for G&N and SCS attitude control modes only. Each displacement of the attitude impulse control (figure 2.13-4, sheet 3) provides an output attitude impulse command to two RCS engines for a duration of  $18 \pm 4$  ms. The pulses command body angular rates of approximately 3 arc min/sec.

#### 2.3.3.2.2 G&N Local Vertical.

The G&N local vertical mode is an extension of G&N attitude control. The purpose of this mode of operation is to accurately maintain the S/C X-axis at a fixed angle with respect to the local vertical (relative to the earth surface) while maintaining the S/C Y-axis normal to the orbital plane. The G&N local vertical mode is an AGC-commanded function. A computer program (not available for AS204A mission) is called by the astronaut by DSKY entry. After IMU alignment, with the S/C X-axis in the direction of the desired orbital path, the computer program provides an orbit rate

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source to command torquing of the IMU at a rate that will maintain the local vertical attitude. This mode may be used to make navigational sightings of earth landmarks by keeping the G&N optics within the area of the earth surface.

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2.3.3.2.3 SCS Attitude Control.

SCS attitude control mode will hold the S/C at an inertial-referenced attitude and will limit S/C drift to the selected deadband limits, normally,  $\pm 5$  degrees in earth orbit. If SCS attitude control is selected after a G&N attitude control function, the attitude reference subsystem is aligned to the IMU (BMAG/AGCU closed loop). If not, an FDAI/AGCU align function is required.

When SCS attitude control is selected, G&N inputs are removed from the FDAI and SCS electronics. The following relay contacts (figure 2.3-4, sheet 2) are activated to supply SCS-generated commands for display and control purposes.

- Relay K4 open—FDAI ball stationary
- Relay K12—Applies body rates to FDAI
- Relay K3 closed to AGCU—Applies attitude errors to FDAI
- Relay K11B—Applies attitude errors to SCS electronics

FDAI/AGCU Align. If the AGCU has not been aligned to the IMU or if a new attitude reference is desired while in SCS attitude control mode, the astronaut will determine S/C attitude from star sightings or from the MSFN. Inertial angles are dialed into the AS/GPI with the ATTITUDE SET dials and the FDAI ALIGN pushbutton is pressed. Relay K2 closes and the AGCU and FDAI ball will drive to the selected attitude.

Manual Maneuvers. After AGCU reference has been established, the S/C can be maneuvered to the desired attitude reference by flying out the errors, using CSS. The ATT SET/OFF switch is activated, relay K23 is activated, the RCS latching relays are closed to the S/M RCS, relays K6 and K9 close, and K20 will open. Attitude error, equal to the difference between ATTITUDE SET dial position and AGCU resolver shaft position, is then applied to the FDAI from the AGCU through K6. Attitude error from the BMAG is removed from the FDAI when K9 activates. When the rotation control is moved out of detent, CSS commands are applied through the ACS to the jet selection logic and auto coils of the RCS engines. At the same time, relays K4 and K5 close providing BMAG/AGCU closed loop. The BMAGs follow S/C rotation and repositions the FDAI ball. When the rotation control is returned to neutral, the BMAG/AGCU loop is opened, relays K4 and K5 open, and the new attitude will hold within the selected deadband.

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When the ATT SET/OFF switch is OFF, relays K6 and K9 de-energize and attitude error signals from the BMAGs are now applied to the FDAI and ACS. If further attitude changes are desired, they can be accomplished by using CSS. The BMAG/AGCU loop will be closed, and opened when the rotation control is returned to neutral. The attitude error needles will indicate the difference between the AGCU and the S/C attitude. The error needles are fly-to needles and will be at full scale if the error is greater than 5 degrees. To fly out the error, the astronaut must fly-to the needles or use the FDAI ball markings until the needles come off full scale, and then fly-to the needle to null the remaining error.

Free Drift. Free drift is normally used during extended periods of time when power and RCS propellant conservation is desired. Free drift can be established in either attitude control mode by placing the SCS CHANNEL switches to OFF, inhibiting all command signals to the RCS auto coils. With an SCS attitude mode selected and an SCS CHANNEL switch to OFF (PITCH or YAW or A&C ROLL and B&D ROLL), relay action closes the BMAG/AGCU loop and updates the ARS while drifting. However, if one BMAG is placed in backup rate and a channel switch is off, relay action rate cages the remaining BMAGs and opens the BMAG/AGCU loop, thus, preventing the ARS from being updated.

2.3.3.2.4 SCS Local Vertical.

SCS local vertical mode is an extension of SCS attitude control. Its purpose is to maintain S/C attitude with respect to the local vertical. When the LCL VERT/OFF switch on MDC-8 is set to LCL VERT, relay K1 energizes and an orbit rate source with a preset level is applied to the BMAG/AGCU servo loop. At present, the preset level established for the orbit rate source is most accurate for a 100-n mi circular orbit and will maintain the attitude reference system at the local vertical with torque rates of 246 degrees/hour, or 4.1 degrees/minute. It will maintain an approximate attitude when the AGCU is aligned to represent S/C attitude when the S/C XZ plane is parallel to the orbital plane at the time LCL VERT is selected. All three RCS channels must be enabled for the local vertical mode. Modifications of the local vertical attitude can be made using CSS. The translation control is also active and available during this mode of operation.

2.3.3.3 Powered Flight (Earth Orbital).

Powered flight includes those modes that provide the capability for velocity changes using the SPS engine. Included in the following discussion are the G&N delta V, SCS delta V, and the manual delta V modes.

2.3.3.3.1 G&N Delta V.

G&N delta V mode is the normal method for velocity changes. Prior to engine ignition, however, G&N attitude control mode must be established.

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System relays apply the following (G&N/SCS switch on MDC-8 set to G&N and ATTITUDE/MONITOR/ENTRY switch set to ATTITUDE (figure 2. 3-5, sheet 1)):

- Relay K7 and K8—Attitude error from CDUs to FDAI
- Relay K9—Attitude error from CDUs to SCS electronics
- Relay K3—Total attitude from IMU to FDAI ball
- Body rates to FDAI and SCS electronics
- RCS latching relay in MESC closed to RCS system

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The FCSM-SCS-RESET/OVERRIDE and G&N-RESET/OVERRIDE switches on MDC-2 may be set to SCS and G&N positions. These switches provide an automatic monitoring of SPS engine combustion performance. If rough combustion occurs, the SPS ROUGH ECO warning light on MDC-10 will light and engine thrust will terminate. A restart can be made by resetting the FCSM switches and then setting them back to SCS and G&N. Or, the monitor can be bypassed by setting the FCSM switches to RESET/OVERRIDE.

Attitude information from the IMU is displayed on the FDAI ball. Attitude errors from the CDUs are also applied to the FDAI ( $\pm 5$ -degree scale) and are used by the SCS to control attitude in response to AGC commands. Rotational rates are displayed by the FDAI rate indicators with a scale range of  $\pm 5$  degrees/second. The computer-controlled velocity change will be monitored on the delta V display. The required velocity less tailoff will be set into the delta V display by the  $\Delta V$  SET switch, using velocity information obtained from the G&N system or MSFN. Minimum deadband is set on MDC-8, the gimbal motor switches, and the inject pre-valve switches on MDC-3 are activated. The SPS gimbal trim angles are determined, set into the AS/GPI by the gimbal position thumbwheels, and gimbal position verified on the GPI. The NORMAL/OFF/DIRECT switch on the delta V display is set to normal.

Approximately 15 seconds prior to ignition, after the digital event timer (MDC-5 and 8) has been set for countdown, the astronaut will command a +X ullage using the translation control. At  $T = 0$ , the AGC will command a signal through the thrust on-off logic and enable the solenoid drivers of the TVC subsystem. The solenoid drivers will then activate the SPS engine ignition coils and SPS thrusting will occur. The lamp portion of the THRUST ON switch on the delta V display will light, verifying the automatic computer command.

System delay (AUTO CONT INTER) logic will terminate the RCS ullage approximately one second after SPS ignition. The computer will command pitch and yaw attitude of the SPS gimbals via the TVC to control the thrust vector. Roll commands will be applied to the roll RCS during the maneuver.

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When the delta V remaining counter indicates zero, thrusting will terminate and the THRUST ON light will go out. The NORMAL/OFF/DIRECT ON switch will be set to OFF and the SPS motor switches, inject pre-valves, and the TVC electronics will be de-activated. Approximately one second after thrust terminates, pitch and yaw control is transferred back to the SCS for the attitude control function.

If a malfunction occurs during the maneuver, a switchover to SCS delta V will allow continuation of the velocity change. If there is no response from the translation control at ullage initiation, the DIRECT ULLAGE pushbutton on the delta V display may be used for the ullage maneuver prior to ignition of the SPS engine. Also, if automatic thrust-on does not occur at  $T = 0$ , the THRUST ON pushbutton on the delta V display will provide engine ignition.

2.3.3.3.2 SCS Delta V.

SCS delta V mode is a primary backup for the G&N delta V. Preliminary to engine ignition, SCS attitude control is established by setting the G&N/SCS switch on MDC-8 to SCS. After SPS engine ignition, the SCS uses S/M RCS roll jets to maintain roll attitude and applies commands to the SPS engine gimbals to control the thrust vector. Relays in figure 2.3-4 apply the following (RCS latching relay in the SECS is closed to the S/M RCS throughout the maneuver):

- Relays K9 and K10—Attitude errors from BMAGs to FDAI
- Relay K11B—Attitude errors from BMAGs to SCS electronics
- Relays K4 and K5 open—FDAI ball stationary
- Body rates to FDAI and SCS electronics (RGA).

The control and display activation process that was performed for the G&N delta V will be performed for SCS delta V. The major differences are as follows:

- Control of attitude and the thrust vector is through the SCS.
- At  $T = 0$ , ignition is initiated manually by pressing the THRUST ON pushbutton on the delta V display.
- Thrust is terminated automatically when the  $\Delta V$  remaining counter (delta V pot.) indicates zero.

As in the G&N delta V mode, if the required command responses to not occur, the same backup controls can be used to perform the delta V.

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In SCS delta V mode, if engine ignition does not occur when the THRUST ON switch is pressed, the NORMAL/OFF/DIRECT ON switch can be set to DIRECT ON. This applies a command signal directly to the SPS engine ignition coils and will initiate thrusting. The NORMAL/OFF/DIRECT ON switch must be set to OFF to terminate engine thrust.

SCS

2.3.3.3.3 Manual Delta V (MTVC).

A manual delta V will be performed only as a backup to a G&N or SCS delta V. Manual thrust vector control is initiated by a CW rotation of the translation control into detent. At this time, relays K4 and K5 will close, providing rate caging of all three BMAGs; and relays K10 and K11B will open removing rate gyro outputs from the FDAI and SCS electronics. The rate-caged BMAGs through relay and K12 will switch BMAG backup-rate signals into the SCS electronics.

In the G&N and SCS delta V modes, TVC servo electronics No. 1 and SPS gimbal drive motor No. 1 was used. When MTVC is initiated, relays K32, K33, and K34 activate. This closes the servo loop for commanding SPS gimbal drive motor No. 2.

Gimbal trim commands are applied through relay K31. When the rotation control is moved out of detent, pitch and yaw commands are applied to motor No. 2 through relay K31 and gimbal position feedback is through relay K32.

The summation of backup rate and proportional CSS commands into the TVC provides a rate-damped manual control of the engine gimbals. The astronaut must keep the rotation control at a given displacement to keep the thrust vector through the c. g. and to fly the correct trajectory.

If CW switches of the translation control are engaged while in G&N delta V, G&N attitude control, or G&N entry mode, attitude errors are not removed from the FDAI. This allows the astronaut to monitor and, if necessary, fly a G&N programmed maneuver using CSS.

2.3.3.4 Entry.

The entry profile consists of the various methods of controlling the S/C for the entry phase of the mission. The entry mode is normally selected after S/M-C/M separation. At separation, the motor-driven RCS transfer switches are closed to the C/M RCS.

2.3.3.4.1 G&N Entry.

G&N manual mode is the primary method of control for entry into the atmosphere for the AS204A mission. Automatic entry may be used in lieu of G&N manual mode.

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G&N Manual. This is normally a backup for the G&N entry automatic mode. The translation control is rotated CW into detent. This removes inertial CDU attitude errors from the SCS electronics. Normally, the astronauts will call up the entry program via the DSKY shortly after S/M-C/M separation.

The entry angle, required pullout angle, and other required entry data is presented on the computer displays. The astronaut can manually perform a controlled g-level entry by using CSS to fly out the commanded attitude errors displayed on the FDAI. The BMAG/AGCU has been closed loop for backup reference in case switchover is necessary.

After .05 g, aerodynamic forces build up sufficiently to stabilize the S/C in the pitch and yaw axes. At this time, CSS will be effective in the roll channel only. The SCS will rate-damp the pitch and yaw channels, and the astronauts will have steering capability by using roll CSS to control the lift vector.

Automatic Entry. The FDAI rate display scale range changes to  $\pm 25$  degrees/second in roll, and  $\pm 5$  degrees/second in pitch and yaw. Deadband is maximum. The rate deadband is  $\pm 2$  degrees/sec.

Prior to .05 G switching, attitude error from the inertial CDUs is applied to the FDAI error indicator through relays K7 and K8, and to the SCS electronics through relay K9. The RGA applies rate gyro body rates to the FDAI and SCS electronics. Relay K3 applies total attitude to the FDAI ball.

At .05 g, the .05 G ENTRY/OFF switch on MDC-8 is set to .05 G ENTRY. The SCS pitch and yaw channels perform rate stabilization only. The roll channel is still subject to computer-controlled roll commands. The AGC will fly the S/C according to a pre-established entry program.

2.3.3.4.2 SCS Entry.

The SCS entry mode is a primary backup to G&N entry mode. When selected, total attitude information to the FDAI is supplied throughout the entry. Prior to .05 g, the BMAGs apply attitude errors to the FDAI and SCS electronics through relays K3 and K9. After .05 g, relays K3 and K9 remove attitude errors from the FDAI and SCS electronics. Relays K4 and K5 close, providing BMAG/AGCU closed loop. For the remainder of entry, attitude errors are not displayed. There is no attitude hold capability. The rate gyros, however, provide rate signals for rate stabilization. The SCS electronics increase rates to a 2-degree/second rate deadband. The FDAI displays total attitude. The astronauts will initiate the necessary commands using CSS to fly a controlled g-level entry. After aerodynamics stability in pitch and yaw, steering capability will be in the roll channel only.

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If, after .05 g, it is necessary to place a BMAG in backup rate, only the BMAG selected by the rate gyro select switch will have its inputs in the SCS for rate stabilization. When backup rate is selected, relays K9, K10, K12, and K15 activate, providing backup rate to the FDAI and SCS electronics. Loss of FDAI ball reference will occur. Relay K12 removes rate gyro output from the FDAI and SCS electronics. The astronauts will control the lift vector with the CSS roll channel. If they wish to decrease the g level, they will roll the S/C to keep the lift vector up. If they wish to increase the g level, they will roll the S/C so that the lift vector is down.

SCS

2.3.4 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

The SCS consists of the following major components:

- Rate gyro assembly (RGA)
- Attitude gyro accelerometer assembly (AGAA)
- Pitch electronic control assembly (pitch ECA)
- Roll electronic control assembly (roll ECA)
- Yaw electronic control assembly (yaw ECA)
- Auxiliary electronic control assembly (aux ECA)
- Display and attitude gyro accelerometer assembly electronic control assembly (DISPLAY-AGAA ECA)
- Rotation control
- Translation control
- Flight director attitude indicator (FDAI)
- Attitude set/gimbal position indicator (AS/GPI)
- Velocity change indicator ( $\Delta V$  display).

2.3.4.1 Rate Gyro Assembly.

The rate gyro assembly contains three identical rate gyros, mounted orthogonally along the spacecraft body axes, and associated gyro electronics. No provision is made for heaters or temperature control of the gyros. Each gyro is a single-axis unit, with the input axis determined by the gyro mounting fixture. Self-test capabilities are provided by torquing coils which enable the gyro to be displaced at a known rate and by spin motor rotation detection circuits which allow monitoring of the gyro spin motor speed. All self-test circuits are completely isolated from operational circuits to prevent a failure in the former from affecting gyro

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operation. The gyro outputs are used by the SCS as primary damping or stabilization signals and, in addition, as negative feedback to null rotational control commands and provide a proportional maneuver rate capability. The rate gyros also provide an indication on the FDAI of the rate-of-attitude change in pitch, roll, and yaw axes. An attitude change about any of the axes results in an output signal which is representative of the rate of displacement.

Each miniature rate gyro assembly consists of a spin motor, damping system, gimbal assembly, quadrilever spring, and self-check circuitry. The gyro spin motor is a 400-cps 3-phase synchronous hysteresis motor powered by 26 volts ac. The maximum time allowed for the gyro to come up to operating speed is 17 seconds. Damping is accomplished by positive displacement of the damping fluid through temperature-controlled orifices. The quadrilever spring provides the torsional restraint required by the gyro, together with radial support for the gimbal assembly. Some important rate gyro characteristics are as follows:

Full-scale range	30°/sec
Input range (to limit stop)	30°/sec
Maximum rate without damage	600°/sec

2.3.4.2 Attitude Gyro Accelerometer Assembly.

The attitude gyro accelerometer assembly contains three body-mounted attitude gyros (BMAGs) and an accelerometer. Electronic control circuits for the gyros and accelerometer are contained in the display and attitude gyro accelerometer assembly electronic control assembly.

2.3.4.2.1 Body-Mounted Attitude Gyros.

The three BMAGs are identical units, mounted orthogonally along the spacecraft body axes, to sense attitude displacement along the pitch, roll, and yaw axes. Each gyro is a single-axis unit, with the input axis determined by the physical mounting in the S/C. A spin motor detection circuit is included in each gyro to allow monitoring of gyro spin motor speed. This will be telemetered data only.

The BMAGs provide information denoting the angular displacement of the spacecraft from a preset attitude. They are initially set to a specific space-stabilized orientation; thereafter, any displacement from this initial setting results in output signals which are representative of the amount of angular displacement. The output signals are used to produce attitude error signals for an attitude-hold mode or for display on the flight director attitude indicator. The outputs may also be applied to the attitude gyro coupler unit (AGCU) for attitude change storage and for conversion to inertial measurement unit (IMU) axes. IMU axes differ from the spacecraft body axes. The AGCU and BMAGs are used as a substitute or backup inertial reference unit for the IMU during the periods when the IMU is

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turned off or has malfunctioned. The BMAGs can also be used to produce attitude rate-of-change information, as backup for the rate gyros.

The BMAGs are single-degree-of-freedom, miniature integrating gyros contained in electrically heated individual packages. The heater will maintain individual BMAG temperature at  $170 \pm 2^\circ\text{F}$ . Degraded gyro operation will result if this temperature is not maintained. The gyro spin motors are 3-phase 24,000-rpm synchronous devices, powered by 13.6 volts 400 cps from a supply in the attitude gyro accelerometer package electronic control assembly. With C/M temperature at  $80^\circ\text{F}$  and the mounting plate temperature at  $55^\circ\text{F}$ , the maximum time allowed for the BMAG to reach operating limits is 40 minutes. A few gyro characteristics are listed as follows.

Acceleration sensitive drift	4 deg/hr
Maximum self-torquing rate	25 deg/sec
Maximum attitude range	$\pm 20$ deg
AGCU coupled torquing limits	$20^\circ$ sec roll, $5^\circ$ sec pitch and yaw

2.3.4.2.2 Accelerometer.

The accelerometer is mounted along the spacecraft X-axis to sense velocity changes along this axis. It is a pendulous-type accelerometer with electronic null and balance. The temperature is maintained at  $170 \pm 2^\circ\text{F}$  under normal operating conditions. A signal output is generated by a velocity change along the X-axis. This velocity change causes the pendulous mass to move, resulting in a change of coupling between the primary and secondary windings of a signal generator. This results in an output signal which is demodulated and amplified to provide acceleration information in the form of digital signals to a counter in the delta V display (paragraph 2.3.4.10). The pendulous mass is returned to null by the balancing action of the electronic caging signal when the velocity change ceases.

2.3.4.3 Pitch, Roll, and Yaw Electronic Control Assemblies.

The pitch, yaw, and roll electronic control assemblies (ECAs) are nearly identical, with slight differences due to different requirements for each axis. The ECAs provide the circuitry for input control signal processing and SCS mode control and configuration. Input control signals consist of attitude error signals from the SCS BMAGs and from the G&N system, minimum impulse commands, rate gyro angular signals, translation and rotation control commands, service propulsion engine gimbal position commands, and SPS engine gimbal rate and position feedback signals. Mode control inputs are received from switches on panel 8 of the main display console (MDC). These input signals are applied to logic-controlled relays which enable circuit configurations corresponding to the desired mode. ECA output signals consist of reaction jet firing commands and SPS gimbal position commands. The reaction jet commands are generated in the jet selection logic portions of the ECAs. Preignition SPS engine gimbal position commands are generated manually at the AS/GPI by thumbwheels which provide input signals to the gimbal control circuits. Post-ignition

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gimbal control is provided by automatic thrust vector control (TVC) circuitry in the pitch and yaw ECAs.

2.3.4.4 Auxiliary Electronic Control Assembly.

The auxiliary electronic control assembly contains the attitude gyro coupling unit and service propulsion system thrust on-off command circuitry. The AGCU portion of the auxiliary ECA receives BMAG signals from the DISPLAY-AGAA ECA and processes the data for display on the FDAI. It also transforms attitude set dial signals to body axes. The SPS engine on-off control circuitry in the AUX ECA receives engine on-off commands from the G&N system or the SCS. These commands are conditioned and applied to the SPS engine solenoid valves.

2.3.4.5 Display and Attitude Gyro Accelerometer Assembly Electronic Control Assembly.

The display and attitude gyro accelerometer assembly electronic control assembly provides the electronic circuitry required to control and power the displays, BMAGs, and accelerometer. The DISPLAY ECA portion consists of the circuitry necessary to receive and condition the following:

- Attitude error signals from the G&N system or the BMAGs to the FDAI attitude error indicators
- Attitude rate-of-change signals from the rate gyros or BMAGs to the FDAI attitude rate indicators
- Feedback signals from the SPS engine gimbals to the gimbal position indicators
- Accelerometer signals from the AGAA to the delta V display integrator.

The AGAA ECA portion consists of circuitry necessary to accomplish the following:

- Accept and condition BMAG inputs for the AGCU
- Accept and condition AGCU torquing commands to the BMAGs
- Control BMAG and accelerometer temperature controls
- Control and condition the accelerometer rebalance loop and inputs to the integrator
- Supply reference voltages to the BMAGs and accelerometer
- Condition the BMAG and accelerometer outputs to telemetry.

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2.3.4.6 Rotation Controls.

Two identical rotation controls are provided to enable manual command of the spacecraft attitude (figure 2.3-8). Each control is a control stick containing breakout switches and transducers (figure 2.3-9) which apply control signals to the reaction jet selection logic circuitry in the pitch, yaw, and roll ECAs. When the stick is moved, the breakout switches close the loop between the BMAGs and AGCU, and control signals from the pitch, yaw, and roll transducers are applied to the appropriate control ECAs. Proportional response to the control stick movement is provided by rate gyro feedback to the ECA electronics (figure 2.3-10). The reaction jet solenoids can also be controlled via the direct application of control voltages from switches in the controller. The latter method, requiring use of the DIRECT MODE switch on MDC-8, does not provide proportional response. With the direct mode enabled and the stick commanding a rotation about one axis, the rate damping circuits in the other axes are active.

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Provision is made to mount the controls at four different locations in the C/M: the right armrest of the left crew couch, both armrests of the right crew couch, and at the navigation station in the lower equipment bay. Normally, one control is attached to the left crew couch mount and the other is used at any of the other three locations. Simultaneous operation of both controls is possible but not advised; however, each control has a locking device to prevent inadvertent operation.

2.3.4.7 Translation Controls.

Two identical translation controls are provided to enable manual command of spacecraft translational maneuvers. (See figure 2.3-8.) Each control is a T-handle type control stick containing switches, which apply control signals to the reaction jet selection logic circuitry in the pitch, yaw, and roll ECSs (figure 2.3-11). The reaction jets are activated in groups of two or four, depending upon the direction of desired translation. Left-right and up-down translations are accomplished by firing two reaction control jets with the same direction of thrust. Forward and reverse translations are accomplished by firing the four forward thrusting or four rearward thrusting reaction control jets. The translation maneuver commanded is in direct response to the direction in which the T-handle is moved.

The primary control has switches which initiate a spacecraft abort if the T-handle is rotated counterclockwise. Both controls have switches which enable manual thrust vector control and disable automatic attitude control if the T-handle is rotated clockwise. Each control has a locking device to prevent inadvertent operation of the translation control.

Both controls are mounted in the C/M on the left armrest of the crew couch. The primary control is identified with yellow stripes and is the only one provided with abort switching capability.

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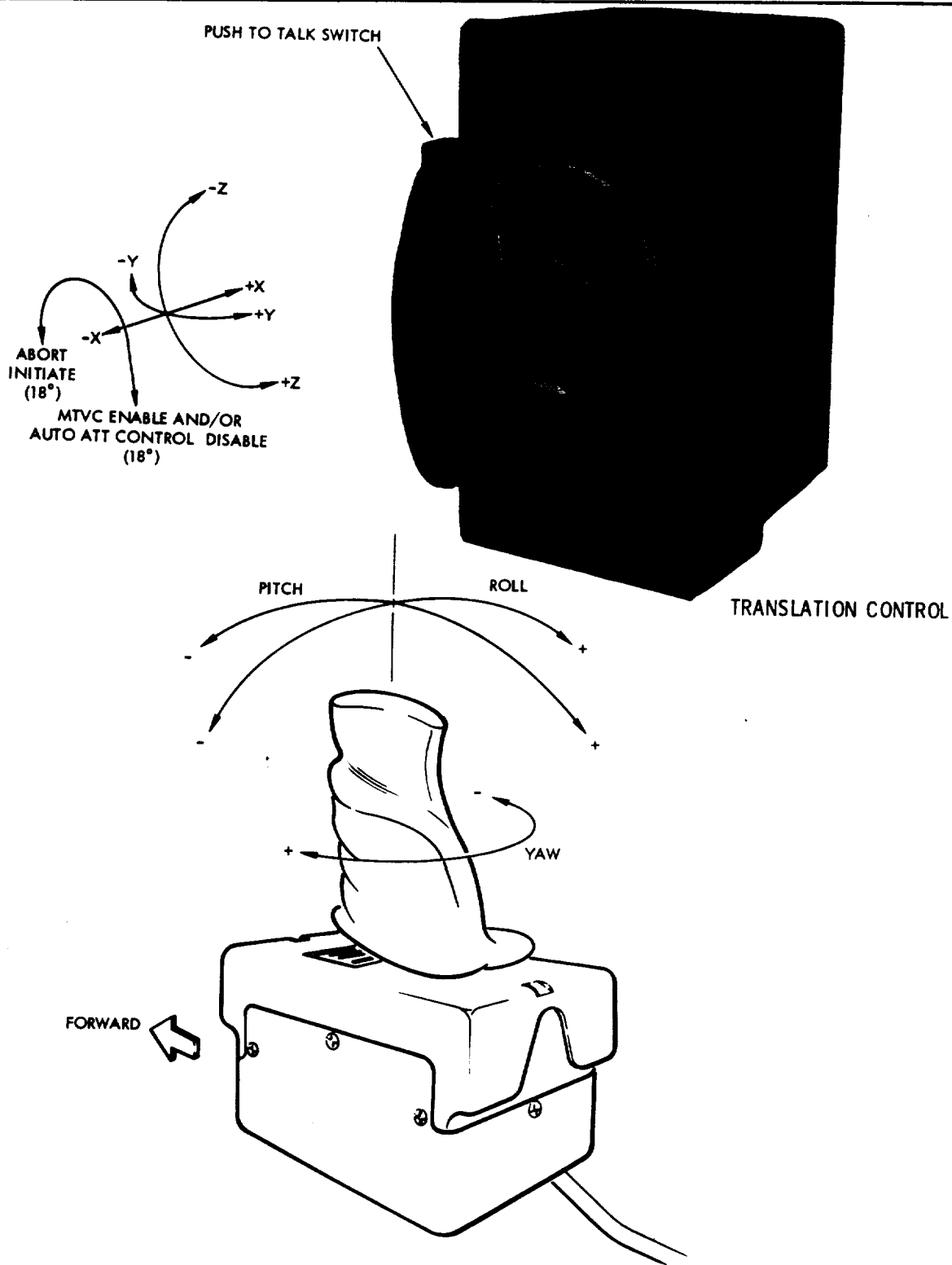


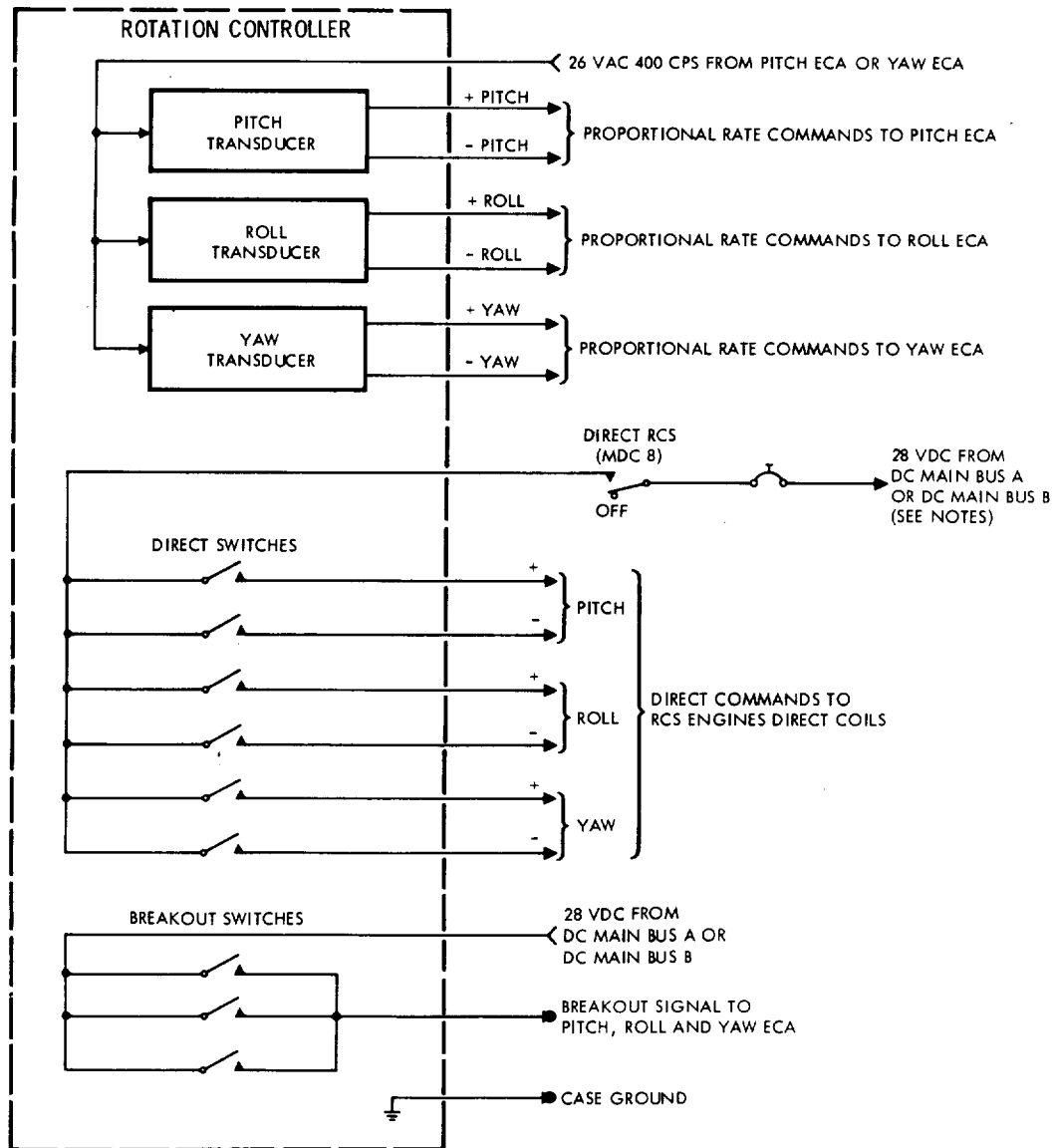
Figure 2.3-8. Rotation and Translation Controls

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- NOTES: 1. DC main bus A supplies power to direct switches in rotation control No. 1.  
2. DC main bus B supplies power to direct switches in rotation control No. 2.

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Figure 2.3-9. Rotation Control Schematic

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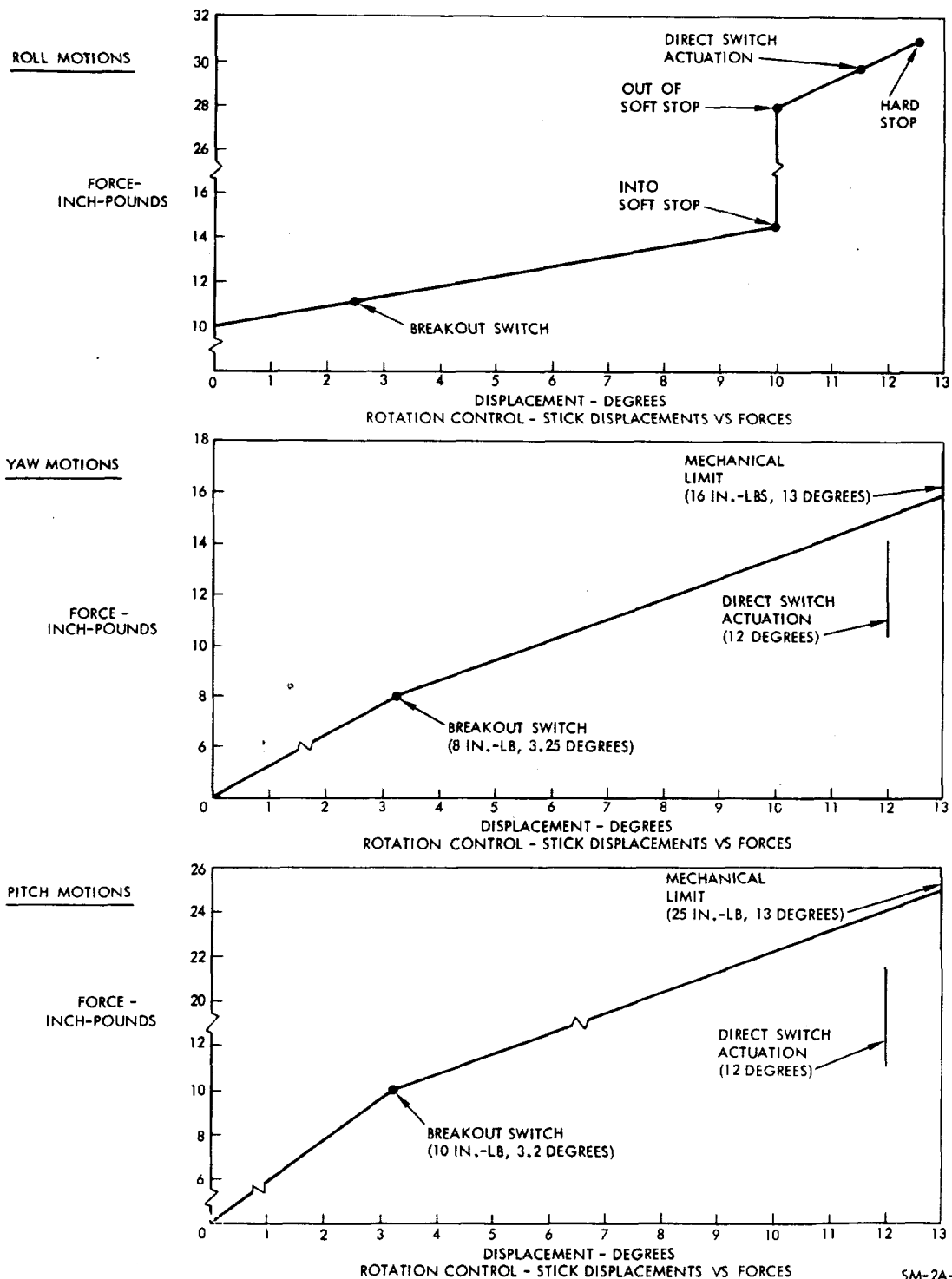
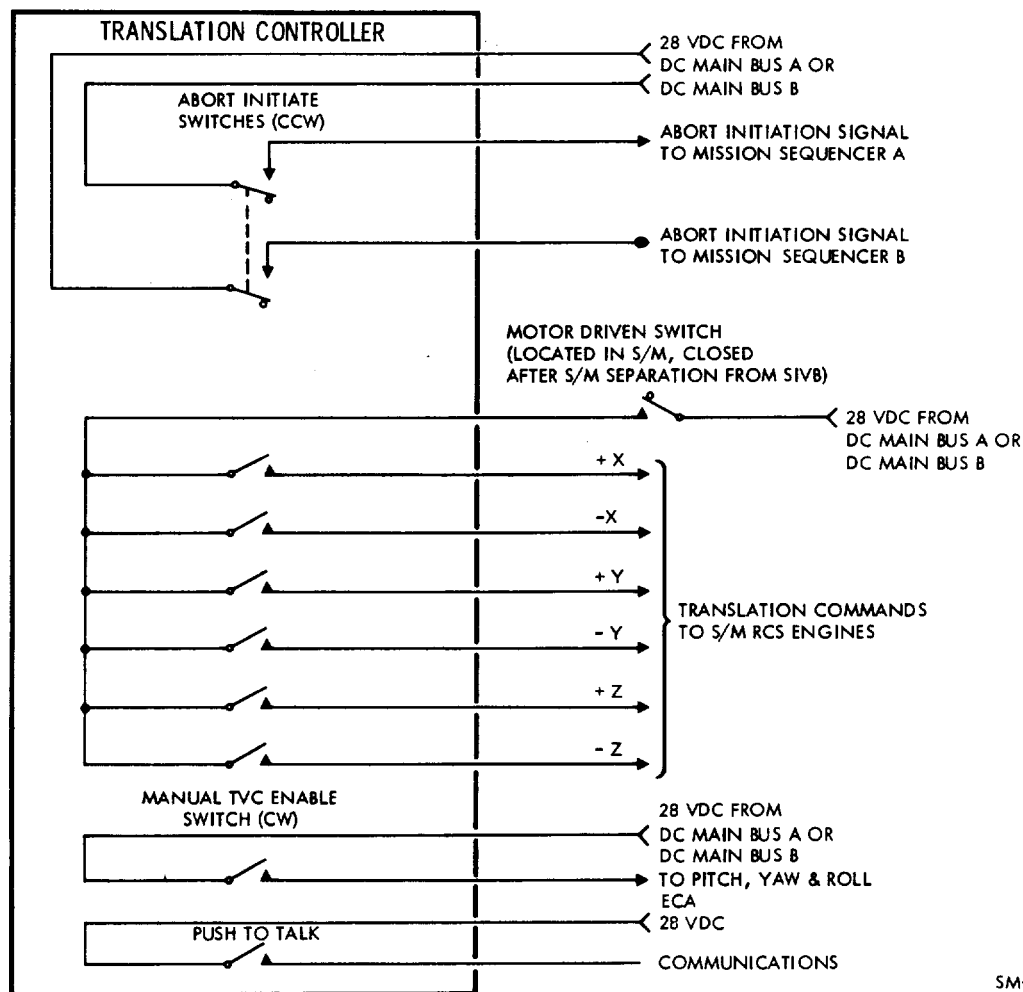


Figure 2.3-10. Rotation Control Charts

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Figure 2.3-11. Translation Control Schematic

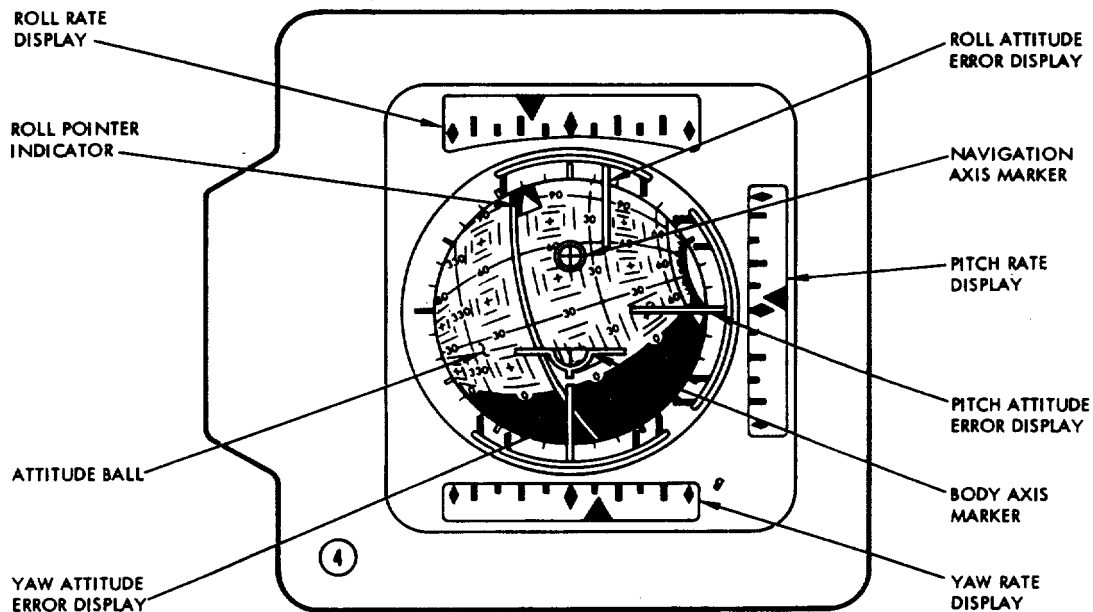
2.3.4.8 Flight Director Attitude Indicator.

The flight director attitude indicator, located on MDC-4, provides attitude, attitude error, and attitude rate-of-change display information. (See figure 2.3-12.) The FDAI indicates attitude rate of change and attitude error on indicators and spacecraft attitude on a 3 degree-of-freedom, inertially referenced ball and roll indicator. The roll rate display is located across the top of the FDAI. The pitch rate display is located along the right side of the FDAI. The yaw rate display is located across the bottom of the FDAI. The attitude error displays are pointers which move across the face of the ball. The rate and error displays are fly-to displays. The roll attitude pointer is located at the top and points down towards the center of the ball. The pitch attitude pointer is located at the right and points left toward the center of the ball. The yaw pointer is located at the

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DISPLAY	AXIS		
	Pitch ( $\theta$ )	Yaw ( $\psi$ )	Roll ( $\phi$ )
Attitude Ball	+55°	+21°	
Roll "Bug"			+21°
Attitude Error Indicators	0°	0°	-2.5°
Angular Rate Indicators	-.1°/Sec	-.2°/Sec	+.3°/Sec

NOTE: On this illustration, the attitude ball display is read with reference to the navigation axis marker.

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Figure 2.3-12. Flight Director Attitude Indicator

bottom and points up toward the center of the ball. The FDAI is located in the center of the display. The ball face is marked in degrees of pitch and yaw and is referenced to the IMU axes. Two reference markers are located on the face of the display to indicate attitude in reference to either spacecraft body axes or IMU (navigation) axes. The body axes marker is on the lower face of the display. The IMU or navigation axes marker is located on the upper face of the display. Roll attitude is the IMU reference and is indicated by the roll indicator (bug) which travels around the circumference of the ball. Roll attitude zero reference is located at the top of the ball.

FDAI display operation will vary, depending upon mode. The rate display is operative at all times. Each rate indicator has a calibrated display scale, with the range of the scale dependent upon the mode selected. Maximum full-scale deflection will be as indicated in the following tabulation.

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Mode	Full-Scale Deflection		
	Pitch	Roll	Yaw
Delta V modes	$\pm 5^\circ/\text{sec}$	$\pm 5^\circ/\text{sec}$	$\pm 5^\circ/\text{sec}$
Entry modes and monitor mode	$\pm 5^\circ/\text{sec}$	$\pm 25^\circ/\text{sec}$	$\pm 5^\circ/\text{sec}$
All other modes	$\pm 1^\circ/\text{sec}$	$\pm 1^\circ/\text{sec}$	$\pm 1^\circ/\text{sec}$

SCS

The attitude error display function depends upon mode. During attitude hold modes, the attitude error pointers display attitude changes within the selected deadband. The maximum deadband will allow approximately  $\pm 5$  degrees of spacecraft movement in any axis, which is equivalent to full-scale deflection for the attitude error pointers. This results in easily discernible pointer movement. The minimum deadband allows approximately  $\pm 0.5$  degrees of spacecraft movement in any axis, which results in very little pointer movement. In SCS control modes, the attitude error signals are derived from the BMAGs or AGCU. The AGCU alone provides the driving signals only when used in conjunction with the ATT SET switch for a dialed attitude change. In G&N modes, the attitude error signals are derived from the G&N coupling display units (CDUs). Full-scale deflection varies depending upon the mode selected, as indicated by the following tabulation.

Mode	Full-Scale Deflection		
	Pitch	Roll	Yaw
Entry modes	$\pm 5^\circ$	$\pm 25^\circ$	$\pm 5^\circ$
Monitor mode	$\pm 15^\circ$	$\pm 25^\circ$	$\pm 15^\circ$
All other modes	$\pm 5^\circ$	$\pm 5^\circ$	$\pm 5^\circ$

The gimballed attitude ball is colored half gray and half black, with the line of separation at the 0-degree to 180-degree pitch angle. This two-color scheme permits rapid recognition of the specific pitch hemisphere being displayed. There are two concentric circles located at 90-degree yaw/0-degree pitch and 270-degree yaw/0-degree pitch. The inner circles are solid red 30-degree circles which represent the base of a cone with the apex at the center of the ball. This area denotes possible IMU gimbal lock. The outer circles enclose a red 40-degree circle which also represents the base of a cone with the apex at the center of the ball. This area denotes attitudes which result in AGCU inaccuracy. The ball is read against one of two reference marks, depending upon the mode of operation. The IMU axes reference mark is the upper marker ( $\oplus$ ) which indicates spacecraft attitude in pitch and yaw axes with reference to the IMU gimbals or stability axes. The body axes marker is the lower marker ( $\sim$ ) which indicates spacecraft attitude with reference to the body axes. The included angle between the markers is 32 degrees. The roll indicator is referenced to the zero mark on the periphery of the ball display face in all operational modes. In SCS modes, the ball is driven only during manual maneuvers, during FDAI alignment, and after 0.05 g is sensed during entry. During these functions, the ball is driven by signals received from the AGCU. In G&N modes, the ball displays IMU gimbal angles. Figure 2.3-13 provides a tabular listing of the various FDAI display configurations.

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SCS			
FLIGHT CONTROL MODES	SCS Entry	SCS ΔV	SCS Local Vertical Attitude Control
Total Attitude (Ball)	Before 0.05 Gs, ball driven only during manual maneuver or FDAI alignment; after 0.05 Gs driven continuously.	Ball driven only during manual maneuver or FDAI alignment.	Ball driven only during manual maneuver or FDAI alignment.
Attitude Errors	BMAGs P & Y ±5° max deflection; R ±25° max deflection.	BMAGs P, Y, & R ±5° max deflection.	BMAGs P, Y, & R ±5° max deflection.
Attitude Rate Errors	Rate gyros (BMAGs when backup rate switch actuated). P & Y ±5°/sec deflection. R 25°/sec deflection.	Rate gyros (BMAGs when backup rate switch actuated). P, Y, & R ±5°/sec deflection.	Rate gyros (BMAGs when backup rate switch actuated). P, Y, & R ±1°/sec deflection.
Roll Bug	AGCU roll angle	AGCU roll angle	AGCU roll angle
G&N			
FLIGHT CONTROL MODES	G&N Entry	G&N ΔV	G&N Attitude Control Monitor
Total Attitude (Ball)	Ball repeats IMU position.	Ball repeats IMU position.	Ball repeats IMU position
Attitude Errors	CDU P, Y, & R ±5° max deflection. R ±25° max deflection.	CDU P, Y, & R ±5° max deflection.	CDU P, Y, & R ±5° max deflection.
Attitude Rate Errors	Rate gyros (BMAGs when backup rate switch actuated). P & Y ±5°/sec deflection. R ±25°/sec deflection.	Rate gyros (BMAGs when backup rate switch actuated). P, Y, & R ±5°/sec deflection.	Rate gyros (BMAGs when backup rate switch actuated). P, Y, & R ±5°/sec deflection.
Roll Bug	IMU roll angle	IMU roll angle	IMU roll angle

Figure 2.3-13. FDAI Display Configuration

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2.3.4.9 Attitude Set/Gimbal Position Indicator.

The attitude set/gimbal position indicator (AS-GPI) provides two separate functions. The attitude set portion enables FDAI-AGCU alignment and provides a reference for acquiring new attitudes. The gimbal position display portion provides positioning control of the SPS engine gimbal angles and displays gimbal position. The attitude set portion provides a comparison of the angle between the attitude displayed on the ATTITUDE SET indicators and the position of the AGCU resolver shaft. It also provides control of the inputs to the FDAI attitude error pointers and aligns the FDAI to the attitude indicated on the ATTITUDE SET indicators. The attitude set function is controlled by manual operation of the thumbwheels. The desired position is dialed by a thumbwheel, with the display providing visual indication of the position selected by the thumbwheel. The attitude display may be used to align the FDAI-AGCU or to indicate a new attitude for the spacecraft. To accomplish FDAI-AGCU alignment, the desired position is set on the attitude set display. The FDAI ALIGN push-button is then pressed. This provides a signal which drives the AGCU stepper motor and control logic to position the AGCU resolver shaft. The stepper motor drives the shaft to the commanded position, resulting in an output from an angle generator to the FDAI ball, driving the ball to the commanded position. To manually maneuver the spacecraft to a pre-determined attitude, the display is set to the desired attitude and the ATT SET switch is placed to ATT SET. The output signal is applied to the attitude error display pointers on the FDAI, providing a manual maneuver indication to the space crew. The display configuration is a fly-to type, with the crew manually maneuvering the spacecraft toward the pointers. (The pointers will peg if the new attitude is in excess of 5 degrees from the original attitude.)

The SPS engine gimbal position display allows positioning of the gimbals and provides indication of gimbal position. Two thumbwheels enable the pitch and yaw engine gimbals to be positioned prior to SPS engine firing. The gimbals position the engine to an attitude which ensures that the SPS engine thrust vector is through the spacecraft center of gravity. Movement of the thumbwheels results in the generation of control signals which engage the SPS gimbal ring torque motor magnetic clutches. Clutch engagement connects the gimbal torque motor and gear train to move the gimbal ring. Position transducers send a signal to the gimbal position displays to indicate the angle of the gimbal. The yaw gimbal position scale is graduated in increments of one-half degree from -5 degrees to +13 degrees. Center is located at the +4-degree position due to an inherent offset in the yaw center of gravity. The pitch gimbal position scale is graduated in increments of one-half degree from -9 degrees to +9 degrees, with the center position at 0 degrees.

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2.3.4.10 Velocity Change Indicator.

The delta V display provides control and display of spacecraft velocity changes. The display portion of the panel consists of the  $\Delta V$  REMAINING indicator, which is a five-digit display. The digital display is set by the variable speed  $\Delta V$  SET switch. Three panel switches control the SPS and RCS engine firing commands. The DIRECT ULLAGE switch is a pushbutton, momentary-contact switch which, when depressed energizes the direct coils of the +X reaction jet solenoids. It serves as a backup for the translation control, which is used under normal conditions for +X translations for SPS fuel settling (ullage). The THRUST ON switch is an illuminated pushbutton, momentary-contact switch which is used to fire the SPS engine in the SCS delta V mode. The switch is enabled when the SPS THRUST switch is in the NORMAL position. The pitch and yaw RCS control and firing circuits are inhibited during SPS engine firing. After ignition, the SPS engine continues to fire until the  $\Delta V$  REMAINING display counts down to zero. The THRUST ON switch is also used to back up the Apollo guidance computer firing commands in the G&N delta V mode in the event of an AGC failure. The SPS THRUST switch provides overall control of SPS engine firing. The NORMAL position enables normal engine firing sequences. The OFF position provides a positive off command as backup in case of a malfunction. The DIRECT ON position provides a positive firing command to the SPS engine.

The  $\Delta V$  SET switch sets up the  $\Delta V$  REMAINING display and logic circuits prior to delta V maneuvers. Pressing the upper section of the  $\Delta V$  switch sets up logic circuitry which causes a slew motor to drive the  $\Delta V$  REMAINING display in the positive direction (increasing velocity). Pressing the lower section of the switch drives the display in the negative direction (decreasing velocity). The switch has two sets of contacts in both the upper and lower positions. Pressing the switch lightly engages the first set of contacts, which results in a signal that will drive the display at a rate of two feet per second. Pressing the switch harder (past an easily felt hard/soft point) engages the second set of contacts, which results in the display being driven at a rate of 64 feet per second. As the display is driven to the desired velocity, the integrator and logic circuit is set to a logical value equal to the desired change. The translation command signal energizes a relay which applies the output of the AGAA accelerometer to the integrator and logic circuit, which compares the desired velocity increment with the actual velocity change received from the accelerometer. When the actual velocity change equals the value set, the  $\Delta V$  REMAINING counter sends a signal to a coincidence detector logic circuit which, in turn, transmits a stop firing command to the thrust control logic. Although this causes the SPS engine to stop firing, some thrusting continues as a result of the tail-off inherent to the engine. The  $\Delta V$  REMAINING display continues to count past zero (i.e., 99999, 99998, 99997, etc.) until no further acceleration is felt. Tail-off effects will be calculated prior to flight and compensated for by the crew when the display is being set up for delta V maneuvers.

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2.3.4.11 Electrical Power Distribution.

See figures 2.3-14 and 2.3-15.

2.3.5 PERFORMANCE AND DESIGN DATA.

SCS

Figure 2.3-16 contains the latest available power consumption data for the Block I SCS. The translation controls were not included in the SCS component breakdown because they do not dissipate a significant amount of power within themselves.

The X-axis accelerometer is a servo-rebalanced pendulous accelerometer. Some of the accelerometer design characteristics are as follows.

Operating range	0.001 g to 2 g
Threshold	$1 \times 10^{-4}$ g (max)
Null torque	$1 \times 10^{-4}$ g (max)
Signal generator sensitivity	50 millivolts/millirad
Signal generator null	1 mr (max)

The body-mounted attitude gyros are single-degree-of-freedom gyros. Some of the gyro design characteristics are as follows.

Acceleration sensitive drift	4 deg/hr/g
Random drift	0.05 deg/hr
Maximum torquing rate	25 deg/sec
Maximum input attitude	$\pm 20$ deg
Gyro threshold	0.02 deg/hr
Gyro transfer function	1.15 millivolts/millirad
Signal generator null	3.5 millivolts
Excitation frequency	$400 \pm 0.01\%$ cps

The rate gyros are single-axis miniature gyros. Some of the gyro design characteristics are as follows.

Full-scale range	$30^{\circ}/\text{sec}$
Input range (to limit stop)	$30^{\circ}/\text{sec}$
Maximum rate without damage	$600^{\circ}/\text{sec}$
Excitation frequency	$400 \pm 0.01\%$ cps
Threshold	$0.02^{\circ}/\text{sec}$

2.3.6 OPERATIONAL LIMITATIONS AND RESTRICTIONS.

2.3.6.1 S/C Attitude Change.

It is recommended that vehicle attitude change be held to maximum rates of less than 20 degrees per second roll and 5 degrees per second in pitch and yaw to prevent possible loss of attitude reference. Because of the AGCU digital logic, the stepping motor can be stepped at a maximum

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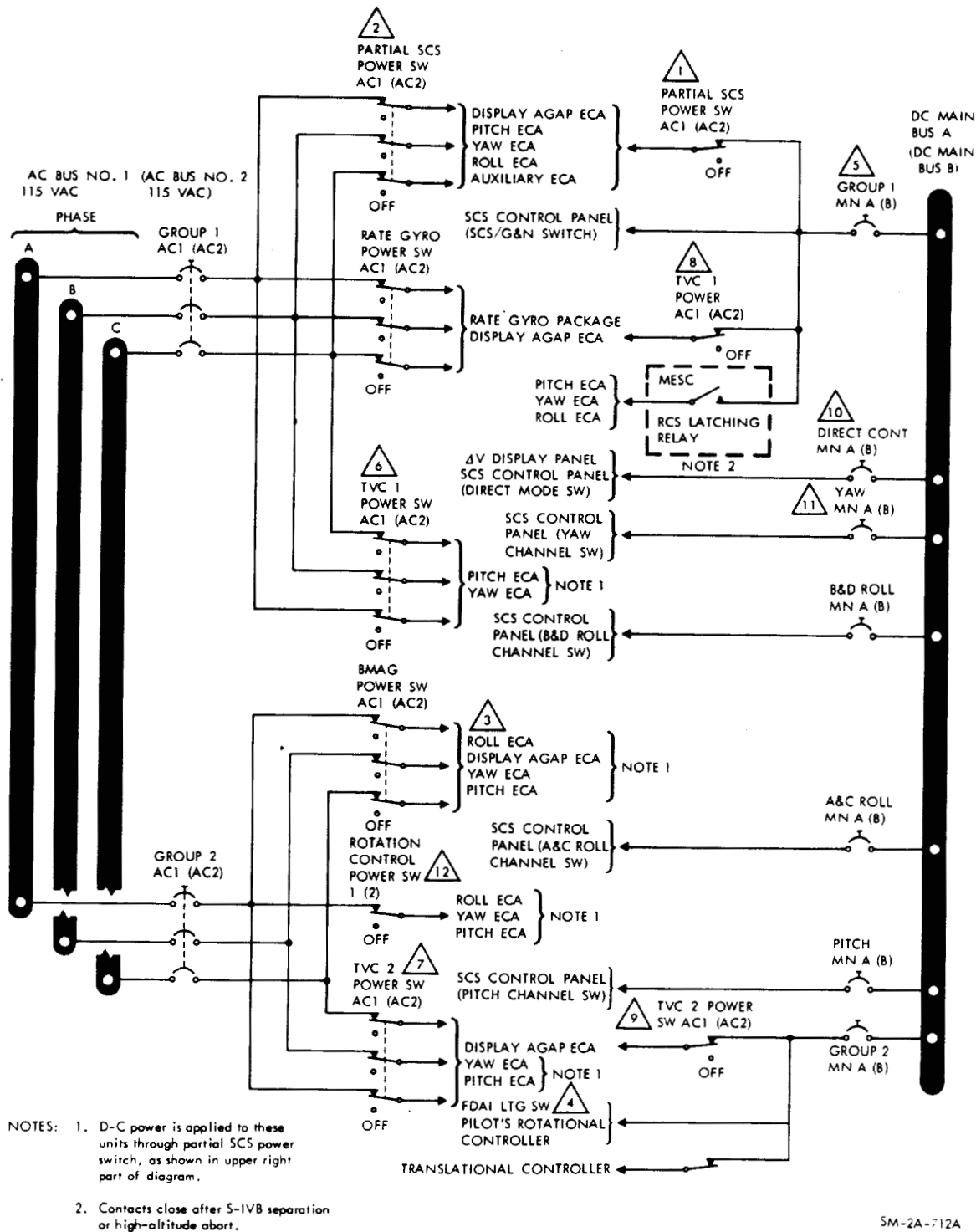


Figure 2.3-14. SCS Power Distribution

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SYSTEM CAPABILITIES	REQUIRED SCS POWER SWITCHES					
	PARTIAL SCS POWER	RATE GYRO POWER	BMAG POWER	ROTATION CONTROL POWER	TVC 1 POWER	TVC 2 POWER
BACKUP RATE	•		•			
CHANNEL ENABLE						
DIRECT ROTATION CONTROL						
PROPORTIONAL ROTATION CONTROL	•	•	• ①	•		
ATTITUDE IMPULSE	•					
G&N SYNC						
TRANSLATION	•					
$\Delta V$ SET					•	
SPS ENGINE IGNITION	• ②					
MANUAL SPS GIMBAL TRIM	•				•	• ③
DIRECT ULLAGE						
THRUST VECTOR CONTROL	•	•	• ④		•	• ⑤
MANUAL THRUST VECTOR CONTROL			•	•		•
ATTITUDE HOLD	•	• ⑦	• ⑤			
RATE DAMPING	•	•	• ①			
FDAI ALIGN	•					
RATE INDICATORS VALID	•	•	• ①			
BALL & ROLL BUG DRIVEN*	•					
ATTITUDE ERROR INDICATORS VALID	• ⑥		• ⑥			

SCS

- NOTES: 1. If backup rate has been selected in any axis. If backup rate has been selected in all 3 axes, RATE GYRO POWER need not be on.
2. PARTIAL SCS POWER must be on if  $\Delta V$  switch is at NORMAL. However, SPS engine can be turned on when all power switches are off, by placing  $\Delta V$  switch to DIRECT ON.
3. TVC 2 POWER switch must be on if manual TVC is engaged.
4. SCS  $\Delta V$  mode only. However, in G&N  $\Delta V$  mode, BMAG POWER must be on if backup rate has been selected in any axis. If backup rate has been selected in all three axes, RATE GYRO POWER switch is set to OFF.
5. SCS modes only; also G&N modes if backup rate has been selected in any axis.
6. SCS modes only, if backup rate has not been selected.
7. RATE GYRO POWER switch may be set to OFF for extended periods of attitude hold.
8. FDAI ALIGN and G&N modes only.

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Figure 2.3-15. SCS Power vs System Capability

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SYSTEM STEADY-STATE POWER CONSUMPTION-WATTS (SQ-1)																
SWITCH	MONITOR				G&N ATTITUDE				SCS ATTITUDE				G&N ENTRY			
	115 VAC 400 CPS				115 VAC 400 CPS				115 VAC 400 CPS				115 VAC 400 CPS			
	ΦA	ΦB	ΦC	DC	ΦA	ΦB	ΦC	DC	ΦA	ΦB	ΦC	DC	ΦA	ΦB	ΦC	DC
PARTIAL SCS PWR (1) POWER FACTOR	25.2 0.94	24.1 0.89	17.6 0.91	16.7	26.0 0.95	24.2 0.89	18.3 0.88	9.0	27.6 0.94	24.3 0.89	18.5 0.88	11.8	25.1 0.94	24.5 0.89	18.0 0.88	19.8
FDAI POWER FACTOR	3.4 1.0				3.4 1.0				*3.4 1.0				3.4 1.0			
RGA POWER POWER FACTOR	5.2 0.98	3.4 0.85	11.8 0.99		5.2 0.98	3.4 0.85	11.8 0.99		*5.2 *0.98	*3.4 *0.85	*11.8 *0.99		5.2 0.98	3.4 0.85	11.8 0.99	
ROT. CONT POWER POWER FACTOR	5.6 0.92				5.6 0.92				*5.6 *0.92				5.6 0.92			
TVC SW NO. 1 POWER FACTOR	16.4 0.96	8.7 0.86	8.7 0.86	16.3	16.4 0.96	8.7 0.86	8.7 0.86	16.3	16.4 0.96	8.7 0.86	8.7 0.86	16.3	16.4 0.96	8.7 0.86	8.7 0.86	16.3
TVC SW NO. 2 POWER FACTOR	11.5 0.75	4.3 0.57	4.2 0.63		11.5 0.75	4.3 0.57	4.2 0.63		11.5 0.75	4.3 0.57	4.2 0.63		11.5 0.75	4.3 0.57	4.2 0.63	
BMAG POWER POWER FACTOR	6.1 0.99	3.4 0.78	7.0 0.80	62.3	6.1 0.99	3.4 0.78	7.0 0.80	62.3	*6.1 *0.99	*3.4 *0.78	*7.0 *0.80	*62.3	6.1 0.99	3.4 0.78	7.0 0.80	62.3
CONT PANEL INPUT (1)				11.82				5.13				4.22				28.13

SYSTEM STEADY-STATE POWER CONSUMPTION-WATTS (SQ-1) (CONTINUED)																
SWITCH	SCS ENTRY				G&N ΔV				SCS ΔV				LOCAL VERTICAL			
	115 VAC 400 CPS				115 VAC 400 CPS				115 VAC 400 CPS				115 VAC 400 CPS			
	ΦA	ΦB	ΦC	DC	ΦA	ΦB	ΦC	DC	ΦA	ΦB	ΦC	DC	ΦA	ΦB	ΦC	DC
PARTIAL SCS PWR (1) POWER FACTOR	27.5 0.94	24.5 0.89	18.3 0.88	22.9	25.7 0.94	24.0 0.88	18.6 0.91	59.4	28.3 0.93	23.3 0.88	19.0 0.91	61.3	26.1 0.94	22.6 0.88	17.6 0.90	12.4
FDAI POWER FACTOR	3.4 1.0				3.4 1.0				3.4 1.0				3.4 1.0			
RGA POWER POWER FACTOR	5.2 0.98	3.4 0.85	11.8 0.99		5.2 0.98	3.4 0.85	11.8 0.99		5.2 0.98	3.4 0.85	11.8 0.99		5.2 0.98	3.4 0.85	11.8 0.99	
ROT. CONT POWER POWER FACTOR	5.6 0.92				5.6 0.92				5.6 0.92				5.6 0.92			
TVC SW NO. 1 POWER FACTOR	16.4 0.96	8.7 0.86	8.7 0.86	16.3	16.4 0.96	8.7 0.86	8.7 0.86	16.3	*16.4 *0.96	*8.7 *0.86	*8.7 *0.86	*16.3	16.4 0.96	8.7 0.86	8.7 0.86	16.3
TVC SW NO. 2 POWER FACTOR	11.5 0.75	4.3 0.57	4.2 0.63		*11.5 *0.75	*4.3 *0.57	*4.2 *0.63		11.5 0.75	4.3 0.57	4.2 0.63		11.5 0.75	4.3 0.57	4.2 0.63	
BMAG POWER POWER FACTOR	6.1 0.99	3.4 0.78	7.0 0.80	62.3	6.1 0.99	3.4 0.78	7.0 0.80	62.3	6.1 0.99	3.4 0.78	7.0 0.80	62.3	6.1 0.99	3.4 0.78	7.0 0.80	62.3
CONT PANEL INPUT (1)				23.07				13.33				6.95				5.65

NOTES:

1. Power measurements made in each mode.
- \*2. Power consumption assumed same in each mode. Asterisk indicates mode in which measurement was made.
3. Measurements made with SPS engine off. (Two solenoids and 2 relays.)
4. Line losses and inverter efficiencies not considered.
5. All values indicated are in watts.
6. Figure does not include energizing RCS engines for maneuvers.

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Figure 2.3-16. SCS Steady-State Power Consumption Data

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rate of 100 steps per second in roll and 25 steps per second in pitch and yaw. This is equivalent to gyro torquing rates of 20 degrees per second in roll and 5 degrees per second in pitch and yaw. Therefore, if vehicle rates exceed the gyro torquing rates, the stepping motor will lag behind the vehicle rates. Under this condition, the BMAG-AGCU loop may not be able to maintain the SCS attitude reference.

SCS

### 2.3.7 TELEMETRY MEASUREMENTS.

The following is a complete listing of all SCS telemetry data that is monitored by flight controllers and ground support personnel. The last column contains the name and type of S/C crew display. The display utilizes the same pickup or signal source as telemetry, unless a separate measurement number is included in the display column.

An asterisk (\*) by the measurement number denotes information which is not available for recording or telemetry transmission during PCM low-bit rate operation.

Figure 2.3-4, sheet 2, identifies telemetry measurements for the SCS yaw channel. Identical measurements in the following list, relative to the roll and pitch channels, are taken from the same circuit junctions as for the yaw channel.

Measurement Number	Description	Sensor Range	Crew Display
* CH 0024 V	Pitch rate		FDAI
* CH 0025 V	Pitch rate manual rotation control	Zero/+5 VRMS	FDAI
* CH 0034 V	Pitch pos feedback in	-6/+6 vdc	None
* CH 0047 V	PTV diff clutch volts comb	TBD	None
CH 0050 V	Pitch rate error amp out	-6.2 to +6.2 vdc	FDAI
CH 0067 V	Pitch integrator/att error summing	TBD	None
* CH 0074 V	MTVC pitch rate	TBD	None
CH 0075 V	Pitch SCS att error	Zero/+10 VRMS	FDAI
* CH 0087 X	+ Pitch/+X solenoid driver out	Off/on event	None
* CH 0088 X	- Pitch/+X solenoid driver out	Off/on event	None
* CH 0089 X	+ Pitch/-X solenoid driver out	Off/on event	None
* CH 0090 X	- Pitch/-X solenoid driver out	Off/on event	None
CH 0100 X	G-N DV mode control	Event	None
CH 0101 X	G-N DV att mode control	Off/on event	None
CH 0102 X	G-N entry mode control	Off/on event	None
CH 0103 X	Monitor mode control	Off/on event	None
* CH 1024 V	Yaw rate	-30 to +30°/sec	FDAI
* CH 1025 V	Yaw manual rotation control	Zero/+5 VRMS	FDAI
* CH 1034 H	Yaw pos feedback in	-8.5/+8.5 vdc	None
* CH 1047 V	YTV diff clutch volts comb	-85 to +85 MADC	None
CH 1050 V	Yaw rate error amp out	-6.2 to +6.2 vdc	FDAI
CH 1067 V	Y integrator/att error summing	-2.5 to +2.5 vdc	None
* CH 1074 V	MTVC yaw rate	TBD	None

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Measurement Number	Description	Sensor Range	Crew Display
CH 1075 V	V yaw SCS att error	Zero/+10 VRMS	FDAI
* CH 1087 X	+ Yaw/+X solenoid driver out	Off/on event	None
* CH 1088 X	- Yaw/+X solenoid driver out	Off/on event	None
* CH 1089 X	+ Yaw/-X solenoid driver out	Off/on event	None
* CH 1090 X	- Yaw/-X solenoid driver out	Off/on event	None
CH 1100 X	SCS DV mode control	Event	None
CH 1101 X	SCS att mode control	Event	None
CH 1102 X	SCS entry mode control	Event	None
CH 1103 X	SCS local vertical mode control	Event	None
CH 1104 X	MTVC mode control	Event	None
* CH 2015 V	Combined AG SMRD	0 to 5 vdc	None
* CH 2024 V	Roll rate	TBD	FDAI
* CH 2025 V	Roll man rotation control out	Zero/+5 VRMS	FDAI
* CH 2026 V	Combined RG SMRD	-0 to +5 vdc	None
* CH 2030 T	Combined attitude gyro temp	0 to +5 vdc	AGAP TEMP LIGHT
CH 2050 V	Roll rate error amp out	-6.2 to +6.2 vdc	FDAI
* CH 2070 V	Roll attitude error amp out	-25/+25 vdc	None
CH 2075 V	Roll SCS att error	Zero/10 VRMS	FDAI
* CH 2087 X	+ Roll/+Z solenoid driver out	Event	None
* CH 2088 X	- Roll/-Z solenoid driver out	Event	None
* CH 2089 X	+ Roll/-Z solenoid driver out	Event	None
* CH 2090 X	- Roll/-Z solenoid driver out	Event	None
* CH 2091 X	+ Roll/+Y solenoid driver out	Event	None
* CH 2092 X	- Roll/+Y solenoid driver out	Event	None
* CH 2093 X	+ Roll/-Y solenoid driver out	Event	None
* CH 2094 X	- Roll/-Y solenoid driver out	Event	None
CH 3185 X	.05 g Manual switch	Event	None
* CH 3186 V	DV remaining pot out	-3 to +13 KFPS	$\Delta V$ Counter
CH 4100 H	Resolver sin out pitch att	-12 to +12 VRMS	None
CH 4101 H	Resolver cos out pitch att	-12 to +12 VRMS	None
CH 4102 H	Resolver sin out yaw att	-12 to +12 VRMS	None
CH 4103 H	Resolver cos out yaw att	-12 to +12 VRMS	None
CH 4104 H	Resolver sin out roll att	-12 to +12 VRMS	None
CH 4105 H	Resolver cos out roll att	-12 to +12 VRMS	None
* CH 4320 X	SPS solenoid driver out 1	Event	None
* CH 4321 X	SPS solenoid driver out 2	Event	None
CG 0001 V	Computer digital data 40 bits	Event	Delta V Display

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SECTION 2

SUBSECTION 2.4

SERVICE PROPULSION SYSTEM (SPS)

2.4.1 FUNCTIONAL DESCRIPTION.

SPS

The service propulsion subsystem provides the major impulse for all major velocity changes (AV's) throughout a mission, plus the S/M abort after the launch escape tower is jettisoned. To perform this function, the subsystem incorporates a helium pressurization system, a propellant feed system, a propellant gauging and utilization system, and a rocket engine. The oxidizer is nitrogen tetroxide, and the fuel is a blended hydrazine (approximately 50% unsymmetrical dimethyl hydrazine and 50% anhydrous hydrazine). The pressurizing gas is helium. The subsystem incorporates displays and sensing devices to permit ground-based stations and the crew to monitor its operation.

A functional flow diagram is contained in figure 2.4-1.

The helium pressure is directed to the helium pressurizing valves which isolate the helium during nonthrusting periods, or allows the helium to pressurize the fuel and oxidizer tanks during thrusting periods. The helium pressure is reduced at the pressure regulators to a desired working pressure. The regulated helium pressure is directed through check valves that permit helium flow in the downstream direction when the pressurizing valves are open, and prevent a reverse flow of propellants during nonthrusting periods. The heat exchangers transfer heat from the propellants to the helium gas to reduce any pressure excursions that may result from a temperature differential between the helium gas and propellants in the tanks. The relief valves maintain the structural integrity of the propellant tank systems if an excessive pressure rise occurs.

The total propellant supply is contained within four similar tanks: an oxidizer storage tank, oxidizer sump tank, fuel storage tank, and fuel sump tanks. The storage and sump tanks for each propellant system are connected in series by a single transfer line. The regulated helium enters into the fuel and oxidizer storage tank, pressurizing the storage tank propellants, and forces the propellant to an outlet in the storage tank which is directed through a transfer line into the respective sump tank standpipe, pressurizing the propellants in the sump tank. The propellant in the sump tank is directed to the exit end into a propellant retention reservoir, retaining sufficient propellants at the tank outlets to permit engine restart capability in a zero g condition. The propellants exit from the respective sump tanks into a single line to the heat exchanger.

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SERVICE PROPULSION SYSTEM

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A propellant utilization valve is installed in the oxidizer line, and is powered only during SPS thrusting periods. The propellant utilization valve aids in maintaining the center of mass in a relatively confined area in the Y - Z plane, in addition to simultaneous propellant depletion. The oxidizer supply and fuel supply are connected from the sump tank to the engine interface flange.

The propellants flow from the propellant sump tank feed through their respective plumbing to the main propellant orifices and filters to the bipropellant valve. The bipropellant valve assembly contains the main propellant valves that are pneumatically controlled and allows the propellant valves to distribute the propellants to the engine injector during thrusting periods, or isolates the propellants from the injector during nonthrusting periods.

The engine injector distributes the propellants through orifices in the face of the injector where the fuel and oxidizer impinge upon each other, atomize, and ignite due to hypergolic ignition.

The ablative combustion chamber absorbs the heat generated within the chamber. The nozzle extension is attached to the ablative chamber and radiates to space.

The engine assembly is mounted to the structure of the service module and is gimballed to permit thrust vector alignment through the center of mass, prior to thrust initiation and thrust vector control during a thrusting period. A flight combustion stability monitor system is employed to monitor the engine for instability during thrusting periods.

Propellant quantity is measured by two separate sensing systems: primary and auxiliary. The sensing systems are powered only during thrust-on periods due to the capacitance and point sensor measuring techniques. The linearity would not provide accurate indications during the zero g SPS nonthrusting periods.

The control of the subsystem is automatic with provisions for manual override.

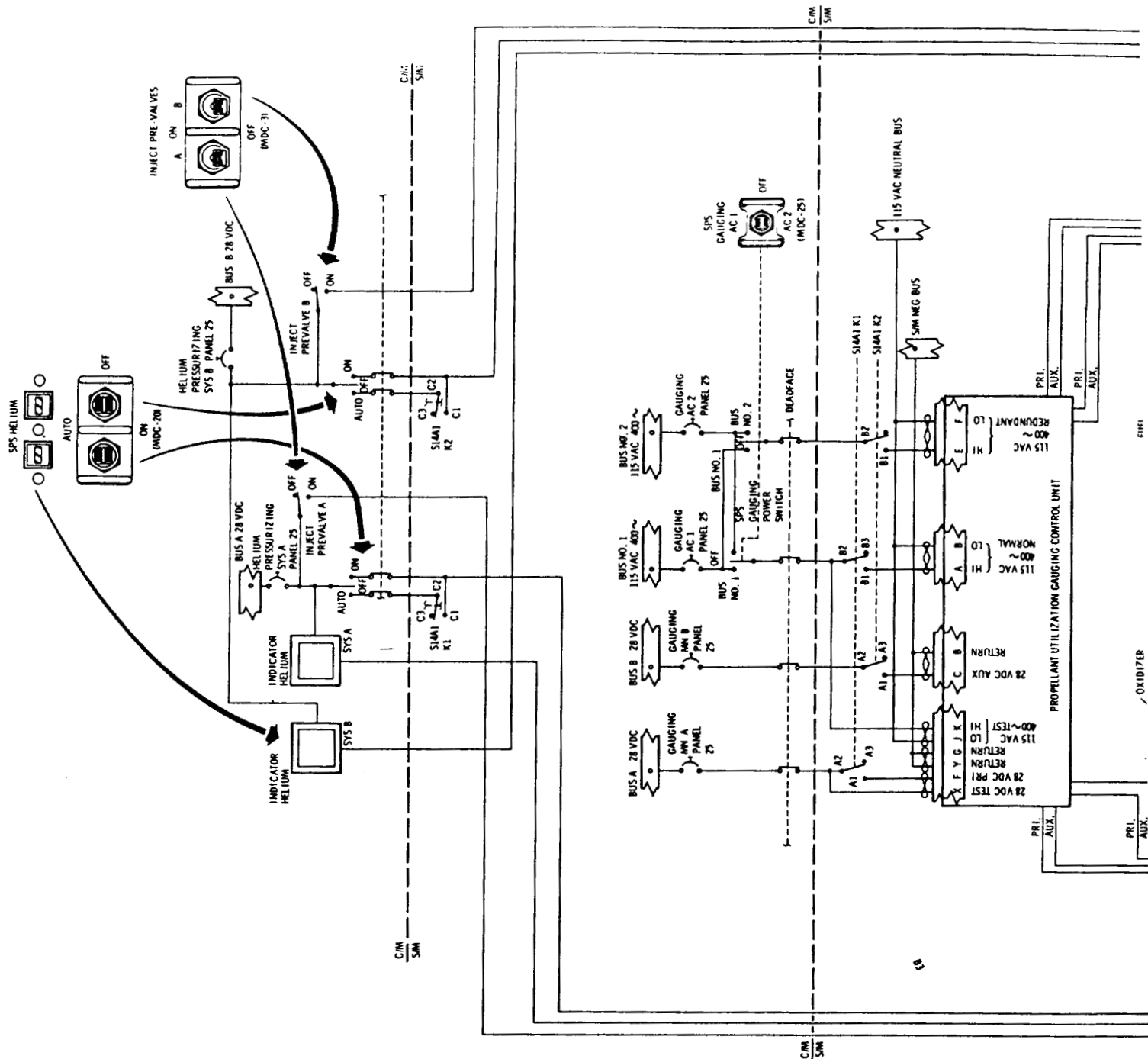
2.4.2 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

2.4.2.1 Pressurization Subsystem.

The pressurization subsystem consists of two helium tanks, two helium pressurizing valves, two dual pressure regulator assemblies, two dual check valve assemblies, two pressure relief valves, and two heat exchangers. The critical components are redundant to increase reliability.

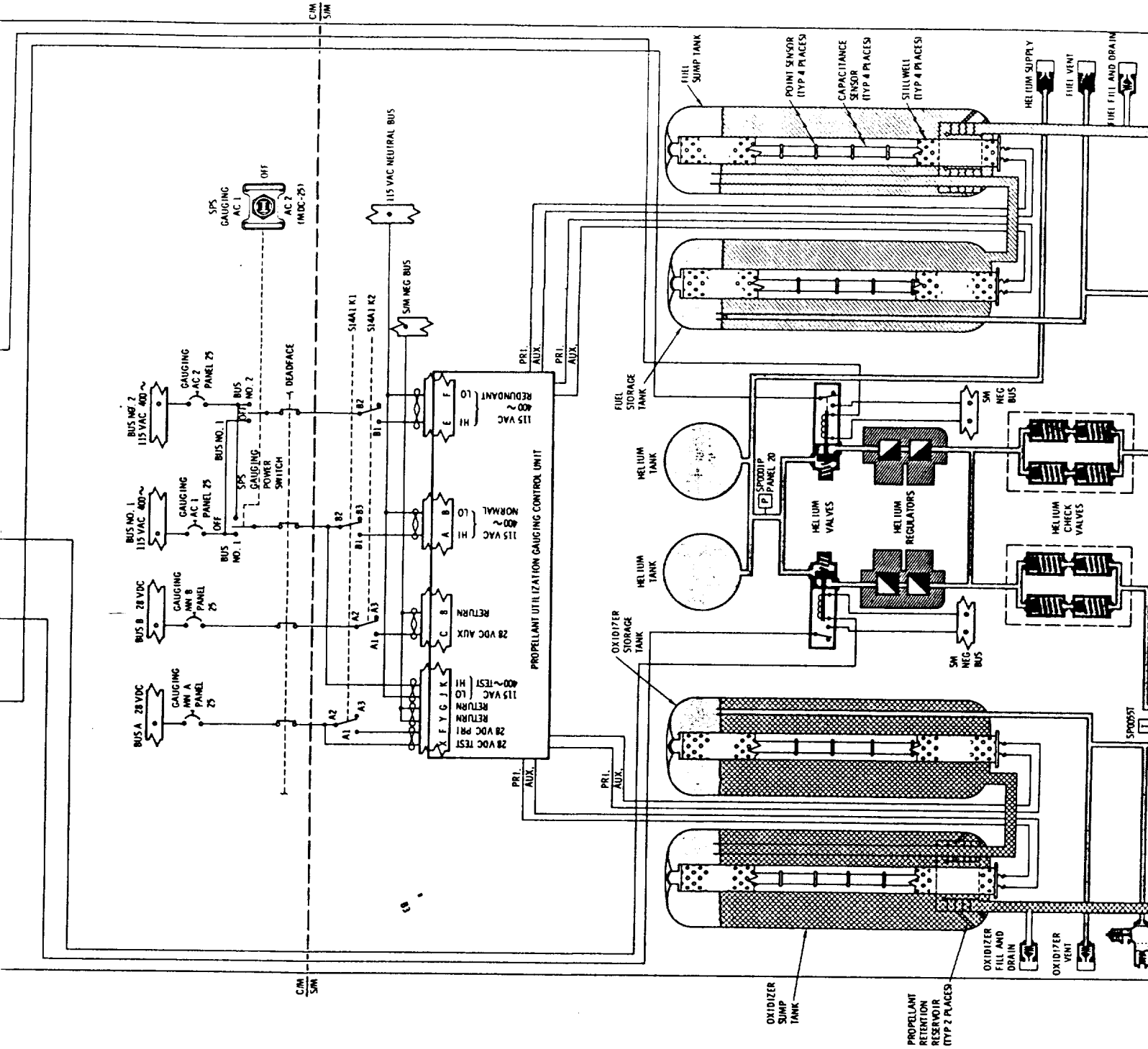
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SERVICE PROPULSION SYSTEM



FOLDOUT FRAME

1



WULDOOT FRAME

2







## Mission

100-100-100

**Figure 2.4-1. SPS Functional Flow Diagram**

## SERVICE PROPULSION SYSTEM

**BOLDOUT FRAME**

4



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2.4.2.1.1 Helium Tanks.

The two helium supply spherical pressure vessels are located in the center section of the service module.

2.4.2.1.2 Helium Pressurizing Valves.

These two continuous duty solenoid-operated valves are normally closed to the helium supply pressure. The valves are energized open and spring-loaded closed. When the helium switches on panel 20 are in the AUTO position, the valves are energized and de-energized by the thrust ON-OFF signal. The valves may be manually controlled by the crew, utilizing the ON and OFF position of the helium switches. Each valve is controlled individually by a separate switch on panel 20.

Each valve contains a position switch which controls a position indicator above each switch on panel 20. When a valve is closed, the position switch is open and the indicator is gray (same color as the panel). When a valve is open, the position switch is closed and the indicator has diagonal lines, indicating the valve is open.

In the event of a failure in the automatic mode of operation, the crew manually enables the pressurizing valve or valves on panel 20. In the event of a problem with one of the regulating units, the crew manually isolates the required pressurizing valve.

2.4.2.1.3 Pressure Regulator Assemblies.

Pressure regulation is accomplished by two pressure regulating units in parallel, downstream of each helium pressurizing valve. Each regulator unit contains a primary and secondary regulator in series, and a pressure surge damper installed on the inlet to each regulating unit.

The primary regulator is normally the controlling regulator, while the secondary is normally open during a dynamic flow condition. The secondary regulator will not become a controlling regulator until the primary, due to a problem, allows a higher pressure than normal, and allows the secondary regulator to function and become the controlling regulator. All regulator pressures are in reference to a bellows assembly that is vented to ambient.

One of the regulating units incorporated in one of the parallel paths is considered the working regulator. The regulating unit in the remaining parallel path is normally locked up when the system is dynamic. The regulator that is normally locked up would not function until the normal regulator allowed the regulated helium pressure to decrease, due to a problem, and allow the normally locked-up regulator to become the functioning regulator.

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2.4.2.1.4 Check Valve Assemblies.

Each assembly contains four independent check valves connected in a series-parallel configuration which provides added redundancy. The check valves will not open until there is a 4-psi pressure differential between the check valve assembly inlet and outlet lines.

2.4.2.1.5 Helium Pressure Relief Valves.

The pressure relief valves consist of a relief valve, a burst diaphragm, and a filter.

In this event, excessive helium and/or propellant vapor ruptures the burst diaphragm and the filter (filter is to be a nonfragmentation type) filters any fragmentation. The relief valve opens and vents the applicable system to space, and will close and reseal after the excessive pressure has returned to the operating level. The burst diaphragm provides a more positive seal of helium than a relief valve. The filter prevents any fragments from the diaphragm from entering the relief valve seat.

A pressure bleed device is incorporated between the burst diaphragm and relief valve. The bleed valve vents the cavity between the burst diaphragm and relief valve in the event of any leakage from the diaphragm. The bleed device is normally open and will close when the pressure increases up to a predetermined pressure.

2.4.2.1.6 Heat Exchangers.

Each unit is a line-mounted, counterflow heat exchanger consisting of a portion of the helium pressurization line, coiled helically within an enlarged section of the propellant supply line. This arrangement causes the helium gas, flowing through the coiled line, to approach the temperature of the propellant.

2.4.2.2 Propellant Subsystem.

This subsystem consists of two fuel tanks (storage and sump), two oxidizer tanks (storage and sump), propellant feed lines, and bipropellant valve assembly.

2.4.2.2.1 Propellant Tanks.

The total propellant supply is contained within four hemispherical-domed cylindrical tanks within the service module. The storage tanks are pressurized from the helium supply, and an outlet transfers the propellant and/or helium gas from the storage tanks through their respective transfer lines to the sump tanks. A standpipe, in the sump tanks, allows the propellant and/or helium gas from the storage tanks to pressurize the sump tanks. Thus, the propellants in the sump tanks are directed in the retention reservoirs, to the outlet, and then to the engine.

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The retention reservoirs are installed in the exit end of the sump tanks only. The umbrella propellant retention screens retain a quantity of propellant in the exit end of the sump tanks, in addition to retaining propellant within the retention reservoir can and in the plumbing from the sump tank outlet to the bipropellant valve of the SPS engine during zero g conditions. An ullage maneuver must be performed prior to a thrust-on signal to the SPS engine by the S/M RCS. The ullage maneuver is performed to ensure that no gases are retained below or aft of the retention screens, in addition to settling the propellants and ensuring that the retention screens are not damaged.

SPS

2.4.2.2.2 Tank Propellant Feed Lines.

The propellant feed lines have flexible bellows assemblies installed to permit alignment of the tank feed plumbing to the engine interface plumbing.

2.4.2.3 Bipropellant Valve Assembly.

The bipropellant valve assembly consists of two gaseous nitrogen (GN<sub>2</sub>) pressure vessels, two injector prevalues, two GN<sub>2</sub> regulators, two GN<sub>2</sub> relief valves, four solenoid control valves, four actuators, and eight propellant ball valves.

2.4.2.3.1 Gaseous Nitrogen (GN<sub>2</sub>) Pressure Vessels.

Two GN<sub>2</sub> tanks are mounted on the bipropellant valve assembly that supply pressure to the injector prevalues. One GN<sub>2</sub> tank is in the primary pneumatic control system A and the remaining GN<sub>2</sub> tank is in the secondary pneumatic control system B.

2.4.2.3.2 Injector Prevalues.

The injector prevalues are two-position solenoid-operated valves, one for each pneumatic control system and identified as A and B. The valve is energized open and spring-loaded closed. The injector prevalue is opened upon command from the crew, panel 3, prior to an engine thrusting period. The injector prevalues energized open allows GN<sub>2</sub> supply tank pressure to flow to an orifice and on into the regulator.

2.4.2.3.3 GN<sub>2</sub> Pressure Regulators.

A single-stage regulator is installed in each pneumatic control system between the injector prevalues and the solenoid control valves. The regulator reduces the supply GN<sub>2</sub> pressure to a desired working pressure.

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2.4.2.3.4 GN<sub>2</sub> Relief Valves.

A pressure relief valve is installed in each pneumatic control system, downstream of the GN<sub>2</sub> pressure regulators, to limit the pressure applied to the solenoid control valves in the event a GN<sub>2</sub> pressure regulator malfunctioned open. The orifice, between the injector pre valve and regulator, is installed to restrict the flow and allow the relief valve to relieve the pressure in event the regulator fails to open, preventing any damage to the solenoid control valves and/or actuators.

2.4.2.3.5 GN<sub>2</sub> Solenoid Control Valves.

Four solenoid-operated, three-way, two-position control valves are utilized for actuator control. Two solenoid control valves are located downstream of the GN<sub>2</sub> regulators in each pneumatic control system. The two solenoid control valves in the primary system are identified in 1 and 2, and the two in the secondary system are identified as 3 and 4. The two solenoid control valves in the primary system control the actuator and ball valves 1 and 2. The two solenoid control valves in the secondary system control the actuator and ball valves 3 and 4. The SPS thrust ON-OFF command controls the energizing or de-energizing of all four solenoid control valves.

2.4.2.3.6 GN<sub>2</sub> Ball Valve Actuators.

Four piston-type, pneumatically operated actuators are utilized to control the eight propellant ball valves. Each actuator piston is mechanically connected to a pair of propellant ball valves; one fuel and one oxidizer. When the solenoid control valves are opened, pneumatic pressure is applied to the opening side of the actuators. The spring pressure, on the closing side, is overcome and the actuator piston moves. Utilizing a rack and pinion gear, linear motion of the actuator connecting arm is converted into rotary motion, which opens the propellant ball valves. When the engine firing signal is removed from the solenoid control valves, the solenoid control valves close removing pneumatic pressure source from the opening side of the actuators. The actuator closing side spring pressure now forces the actuator piston to move in the opposite direction, causing the propellant ball valves to close. The piston movement forces the remaining GN<sub>2</sub>, on the opening side of the actuator, back through the solenoid control valves where they are vented overboard.

2.4.2.3.7 Bipropellant Valves.

The eight propellant ball valves are used to distribute fuel and oxidizer to the engine injector assembly. Four linked pairs, each pair consisting of one fuel and one oxidizer ball valve controlled by a single actuator, are arranged in a series-parallel configuration. The parallel arrangement provides redundancy to ensure engine ignition, and the series arrangement to ensure thrust termination. When the actuators

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are opened, each propellant ball valve is rotated, thereby aligning the ball to a position that allows propellants to flow to the engine injector assembly. The mechanical arrangement is such that the oxidizer ball valves maintain an 8-degree lead over the fuel ball valves upon opening, which results in smoother engine starting transients. Each pair of propellant valves incorporates a potentiometer drive gear and housing. Each housing contains two potentiometers that are mechanically driven: one provides an electrical signal converted into a visual indication of valve position of panel 20, and the remaining provides a signal to telemetry.

2.4.2.3.8 Engine Propellant Lines.

Integral propellant lines are utilized, on the engine, to route each propellant from the interface points in the gimbal plane area to the propellant engine gimbaling, orifices for adjustment of oxidizer/fuel ratio, and screens for keeping particle contaminants from entering the engine.

2.4.2.4 Engine Injector.

The injector is bolted to the ablative thrust chamber attach pad. Propellant distribution to the injector orifices, on the combustion face of the injector, is accomplished through concentric annuli machined in the face of the injector assembly and covered by concentric closeout rings. Propellant distribution to the annuli is accomplished through alternate radial manifolds welded to the backside of the injector body. The injector is regeneratively cooled and baffled to provide combustion stability. The fuel and oxidizer orifices impinge upon each other, atomize, and ignite due to hypergolic reaction.

2.4.2.5 Ablative Combustion Chamber.

The ablative combustion chamber material extends from the injector attach pad to the nozzle extension attach pad. The ablative material consists of a liner, a layer of insulation, integral metal attach flanges for mounting the injector and nozzle extension, and structural outer reinforcement. The only restriction on a restart is dependent upon the SPS WALL TEMP HI caution and warning light, on panel 11, monitoring the outside wall temperature at the throat.

2.4.2.6 Nozzle Extension.

The bell-contoured, nozzle extension is bolted to the ablative thrust chamber exit area. The nozzle extension is radiant-cooled and contains an external stiffener to provide additional strength.

2.4.2.7 Flight Combustion Stability Monitor (FCSM).

The FCSM is an accelerometer package, mounted to the SPS engine injector, to monitor the engine for vibration buildup characteristic of combustion instability.

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The three accelerometers provide signals into an FCSM box assembly which amplifies it and, when the vibration g-level exceeds 180 g's peak to peak for 70±20 milliseconds, a level detector triggers a power switch gating power to the summing logic. The stability monitor will monitor only in a frequency range where instability would occur (approximately 600 to 5000 cycles per second).

The summing logic, if there are two or more rough combustion signals received from the normally closed contacts, will open removing power from the G&N and SCS driver logic; and will close the normally open contacts providing a ground to the SPS ROUGH ECO caution and warning light, on panel 10, informing the crew the SPS engine was shut down due to combustion instability.

The FCSM trigger circuits will provide power to the voting logic relays continuously once unstable combustion is sensed; and power remains applied to the voting logic relays even though the engine is shut down, unstable combustion is no longer sensed, and the SPS ROUGH ECO remains illuminated.

When the engine is shut down to unstable combustion and to remove power from the voting logic relays, the crew would place any one of the following switches to the position indicated to reset the FCSM voting logic:

- a. AUTO-OVERRIDE switches to OVERRIDE.
- b. ΔV switch to OFF.
- c. ATTITUDE-MONITOR-ENTRY switch to either MONITOR or ENTRY.
- d. FCSM SCS and G&N switches to RESET/OVERRIDE.

When the FCSM is reset, the SPS ROUGH ECO light on panel 10 will not be illuminated.

The RESET/OVERRIDE switches, on panel 2, provide a bypass capability of the FCSM system. With the FCSM RESET/OVERRIDE switches, on panel 2, in the RESET/OVERRIDE position, power is not provided to the FCSM box and summing logic assemblies rendering the FCSM inoperative as well as the SPS ROUGH ECO caution and warning light on panel 10. If unstable combustion occurs, the engine continues to thrust.

The FCSM box assembly and summing logic assembly receives power from the SCS through the following switches:

- a. Mode select switch to G&N or SCS mode, panel 8.
- b. ATTITUDE-MONITOR-ENTRY switch to ATTITUDE, panel 8.
- c. ΔV switch to ΔV position, panel 8.
- d. FCSM G&N, RESET/OVERRIDE switch to G&N position, panel 2.
- e. FCSM SCS, RESET/OVERRIDE switch to SCS position, panel 2.

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2.4.2.8 SPS Electrical Heaters.

Twenty-six electrical strip heaters are employed on the propellant line brackets, fuel and oxidizer heat exchangers, propellant utilization valve, bipropellant valve assembly, and the injector tubes. These electrical strip heaters are employed to control the temperature of the entire aft bulkhead and engine areas, thus the propellants.

The strip heaters are controlled as a normal manual function of the crew, on panel 19 (figure 2.4-2), utilizing the SPS HEATER switch. The crew will place the switch to position A or B when the propellant temperature indicator, on panel 20, reads - 40°F (lower red line indication) which is equivalent to a propellant temperature of +40°F. The propellant temperature readout is derived from the engine fuel-feed line measurement (figure 2.4-1). The crew will place the SPS HEATER switch to OFF when the propellant temperature indicator, on panel 20, reads +80°F (upper red line indication) which is equivalent to a propellant temperature of +120°F.

SPS

Propellant Temperature Comparison

Propellant Temperature Indicator Reading °F																
-100	-80	-60	-40	-20	0	+20	+40	+60	+80	+100	+120	+140	+160	+180	+200	
Equivalent Temperature °F																
+0	+13.33	+26.67	+40	+53.34	+66.67	+80	+93.34	+106.67	+120	+133.34	+146.67	+160	+173.34	+186.67	+200	

When the SPS HEATER switch is placed to position A, all 26 heating elements (A) will receive 28 vdc. When the SPS HEATER switch is placed to position B, all 26 heating elements (B) will receive 28 vdc. The OFF position of the SPS HEATER switch removes all electrical power from the SPS heating elements.

2.4.2.9 Thrust Mount Assemblies.

The thrust mount assembly consists of a gimbal ring, engine-to-vehicle mounting pads, and gimbal ring-to-combustion chamber assembly supports. The thrust structure is capable of providing ±8.5 degrees inclination about the Z-axis and ±7.5 degrees about the Y-axis.

2.4.2.9.1 Gimbal Actuator.

Thrust vector control of the service propulsion engine is achieved by dual-, servo-, electro-mechanical actuators. The gimbal actuators are capable of providing control around the Z-Z axis (yaw) of 7 (+1/2, -0) degrees in either direction from a +4-degree null offset, and around the Y-Y axis (pitch) of 6(+1/2, -0) degrees in either direction from a zero-degree null offset. The reason for the 4-degree offset to the +Y axis is due to the offset center of mass in the spacecraft.

Each actuator assembly (figure 2.4-3) consists of four electromagnetic particle clutches, two d-c motors, a bull gear, jackscrew and ram, ball nut, four linear position transducers, and two velocity generators. The actuator assembly is a sealed unit and enclose those portions protruding from the main housing.

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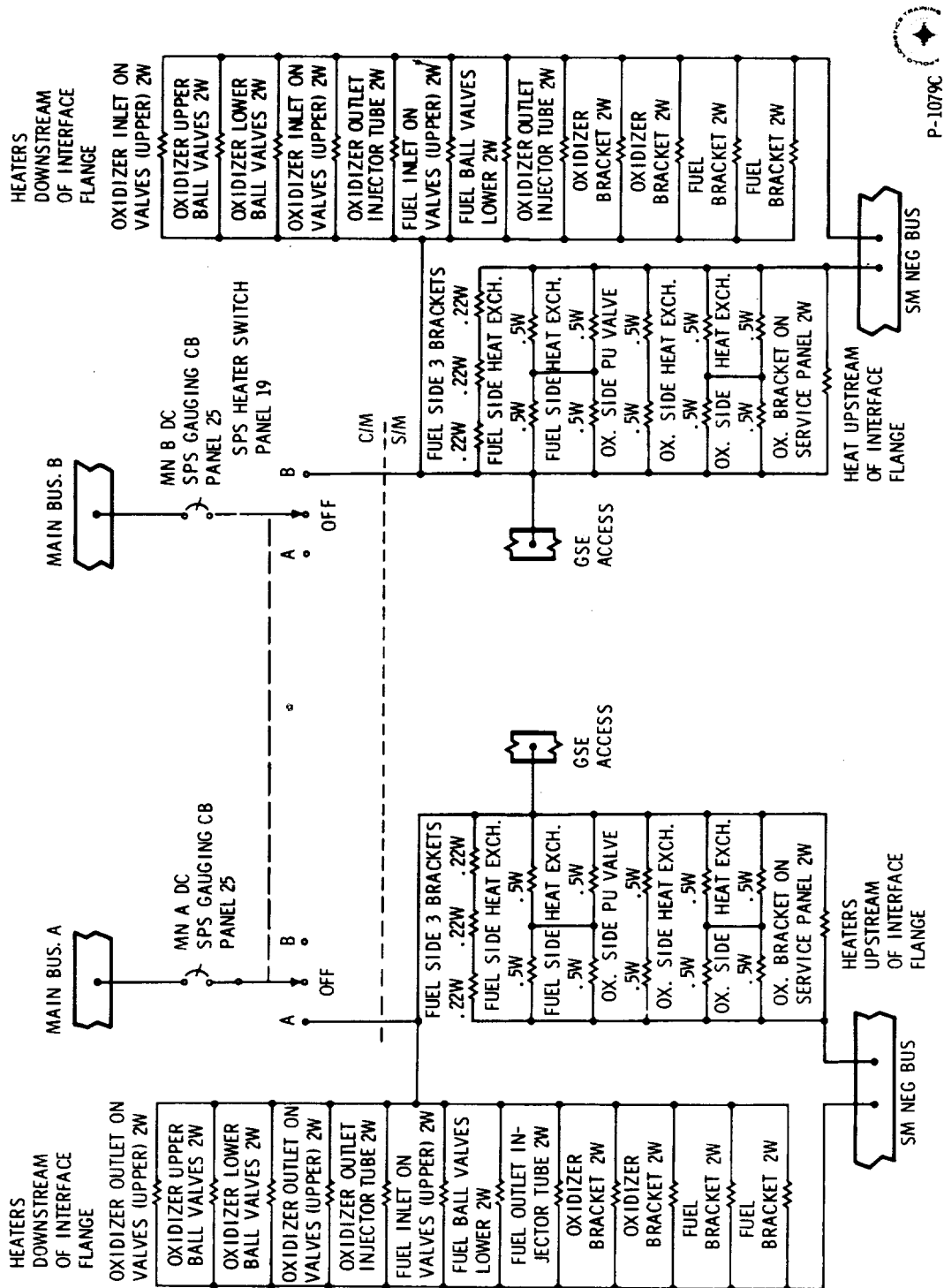
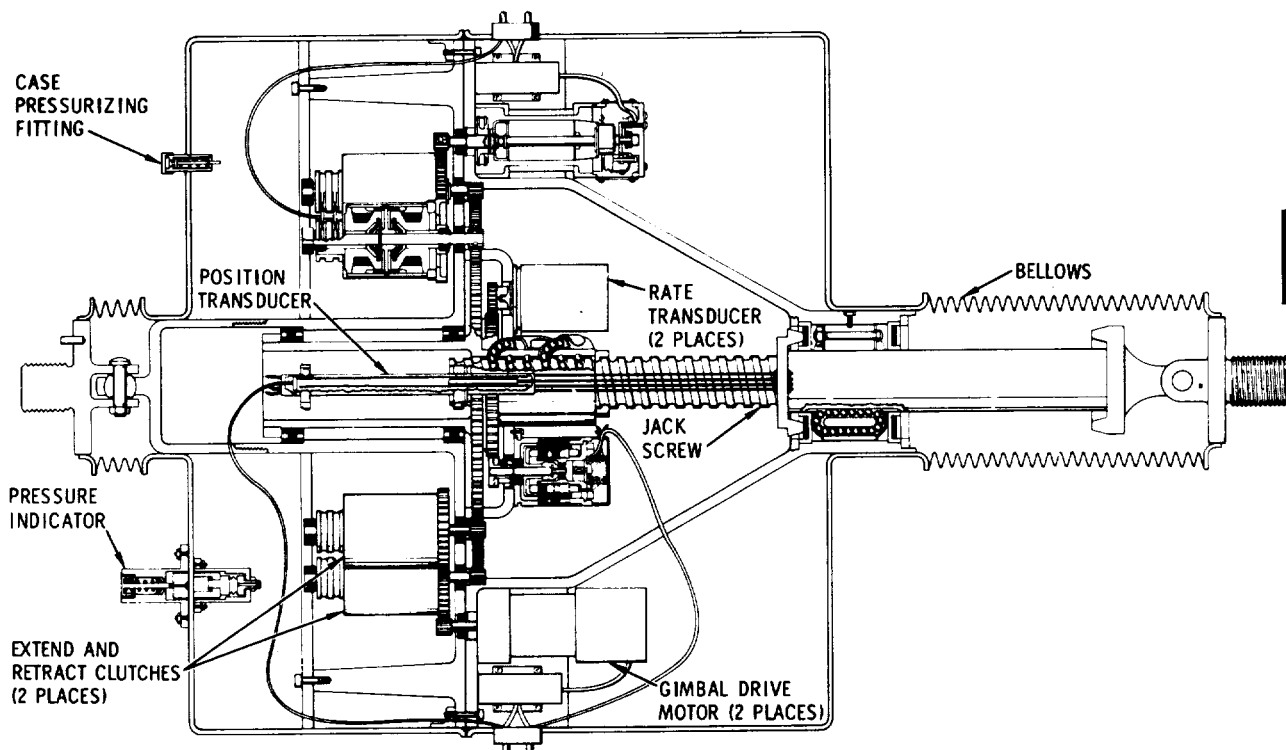


Figure 2.4-2. SPS Electrical Heaters

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Figure 2.4-3. SPS Electro-Mechanical Gimbal Actuator

One motor and a pair of clutches (extend and retract) are identified as system No. 1, and the remaining motor and pair of clutches (extend and retract) are identified as system No. 2 within the specific actuator.

An over and undercurrent relay is employed for each primary gimbal motor (figure 2.4-4), and is controlled individually by a switch on panel 3. When the primary GIMBAL MOTORS switches are placed to the START position, power is applied to the motor-driven switch within the over and undercurrent relay of the primaries. The motor switch then supplies power from the main bus A to the gimbal motor. When the switch is released, it spring-loads to the ON position which activates the over and undercurrent sensing circuitry of the primary relay which monitors the current to the gimbal motor.

The over and under current relay of the primaries are utilized to monitor the current to the gimbal motor due to the variable current flow to the gimbal motor that is dependent upon the gimbal angle change required.

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Using No. 1 yaw system as an example, and identifying the upper motor and clutches in figure 2.4-3 as system No. 1, the operation of the current monitoring system is as follows:

- a. If the relay senses an over or undercurrent to gimbal motor No. 1, the monitor circuitry within the relay will drive the motor-driven switch, removing power from gimbal motor No. 1.
- b. Simultaneously, a fail sense signal is sent from the relay, the SCS, which opens relay K13 removing inputs from the No. 1 clutches and closes relay K14 applying inputs to the No. 2 clutches within the same actuator; and the top contact of K12 opens and the bottom contact of K12 closes for TVC monitor.
- c. Simultaneously a signal is sent to illuminate a caution and warning light on panel 11, to indicate the primary gimbal motor has failed.

The primary switches on panel 3 are then placed in the OFF position. Normally the OFF position is used to shut down the gimbal motors upon the completion of a thrusting period.

The No. 2 systems employ a 70-amp circuit breaker that is located in the service module near the SPS power distribution box.

Using No. 2 yaw system as an example (figure 2.4-4), the operation of the current monitoring system is as follows:

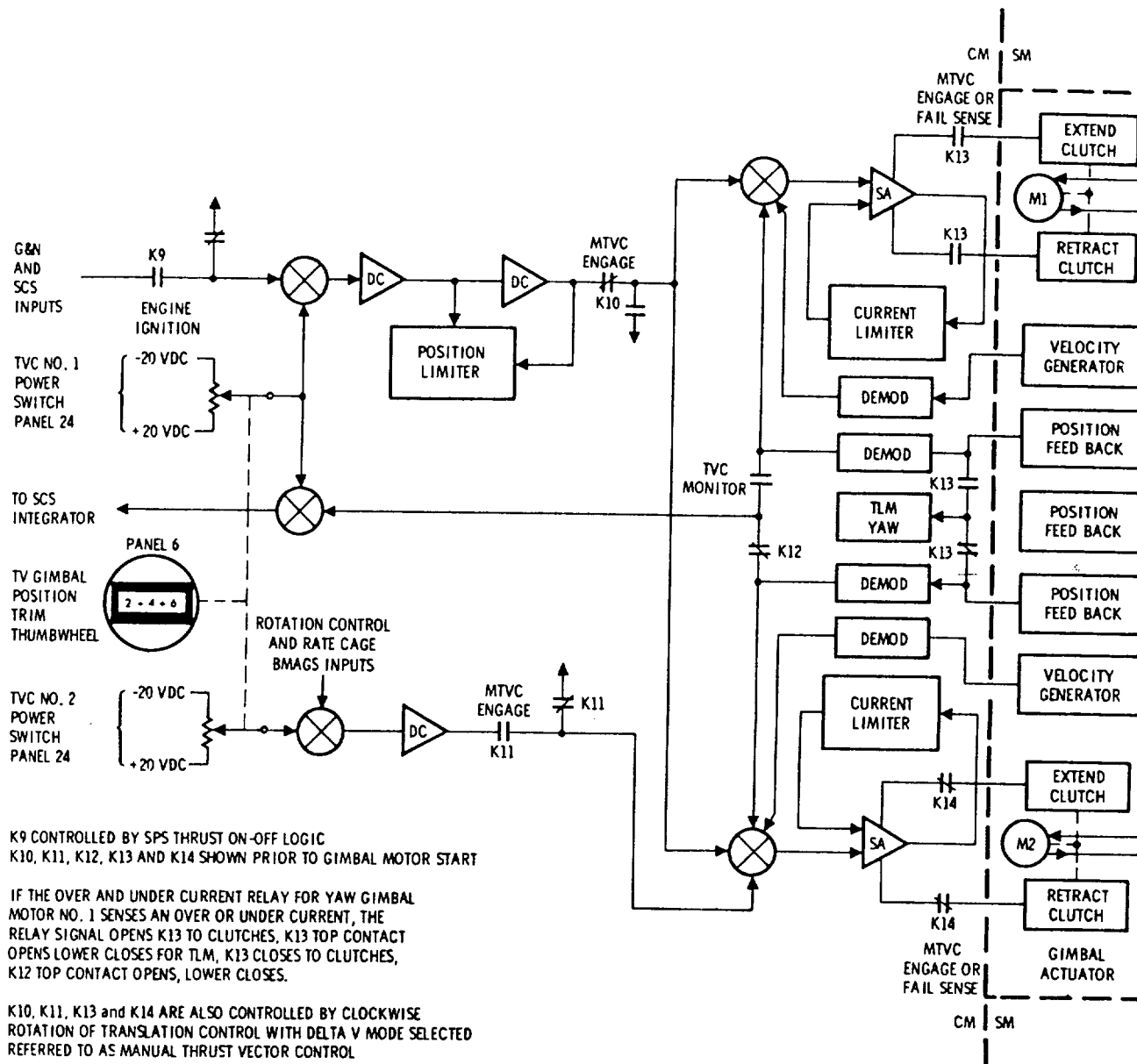
- a. When the secondary GIMBAL MOTORS switches are placed to the START position, power is applied to the motor-driven switch within the over and undercurrent relay of the secondaries. The motor switch then supplies power from the main bus B through the 70-amp circuit breaker, and through the motor-driven switch to the secondary gimbal motor.
- b. When the secondary switch is released, it spring-loads to the ON position which performs no functions on the secondaries.
- c. The 70-amp circuit breaker will monitor the current to the secondary gimbal motor; and if a current of 70 amps is sensed, the circuit breaker in the service module will remove power from the secondary gimbal motor.
- d. There is no fail sense signal sent to the stabilization and control system, and no illumination of the caution and warning light on panel 11 from the secondary system.
- e. If the No. 2 system has failed due to an overcurrent, the circuit breaker removes power from gimbal motor No. 2 only, and that specific actuator is inoperative if the No. 1 system has previously failed.

The secondary switches on panel 3 are then placed to OFF position. Normally, the OFF position is used to shut down the gimbal motors upon the completion of a thrusting period.

The clutches are of a magnetic particle type. The gimbal motor drive gear meshes with the gear on the clutch housing. The gears on each clutch housing mesh and as a result, the clutch housings counterrotate. The current input is applied to the electro-magnet mounted to the rotating clutch housing from the stabilization control system or in the guidance and navigation system through the stabilization control system. A quiescent

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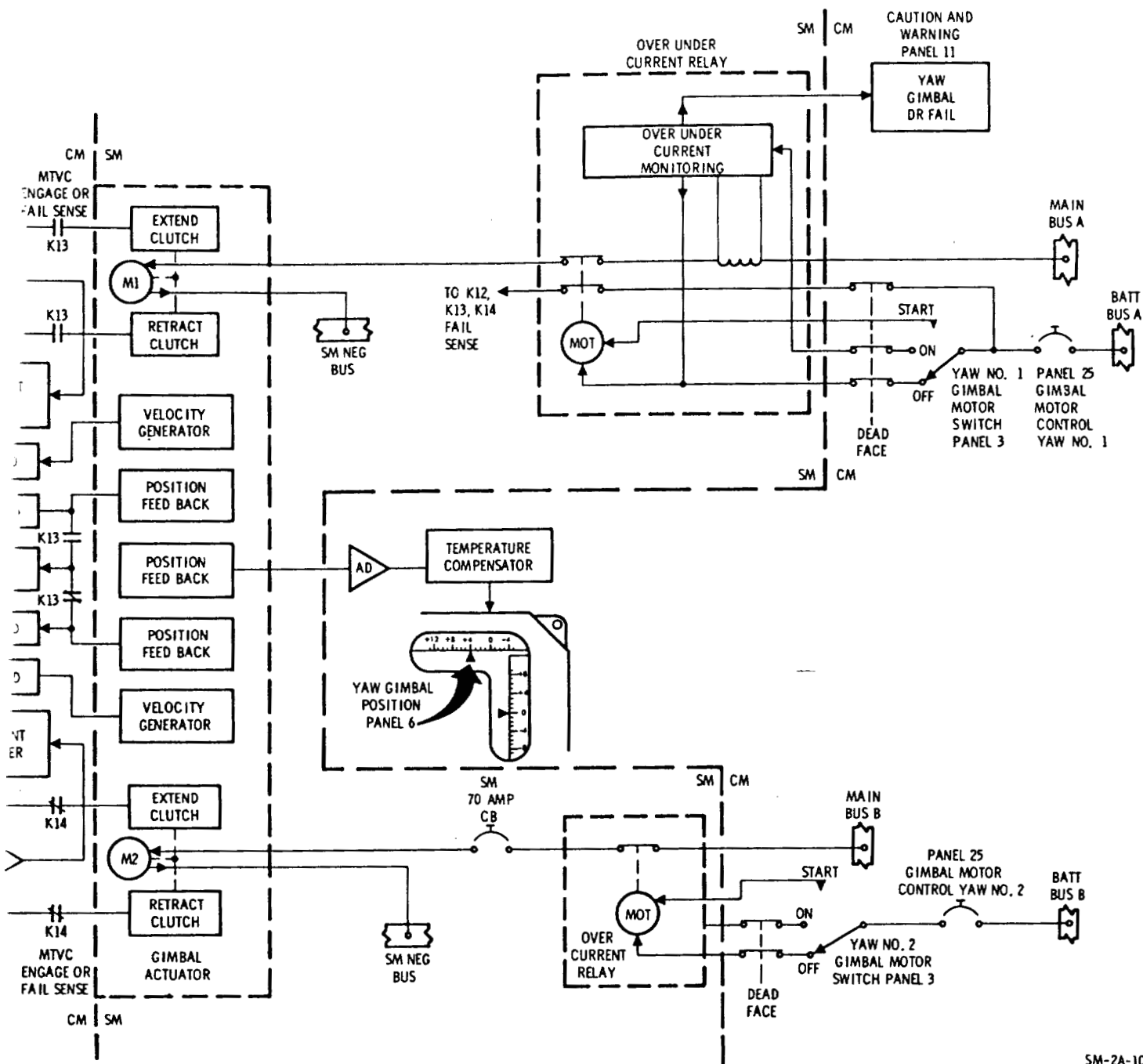






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Figure 2.4-4. SPS Yaw Gimbal Actuator Motor and Clutch Control

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current is applied to the electro-magnet of the extend and retract clutches when the thrust vector POWER switches, on panel 24, are on, which prevents the engine from moving during the boost phase of the mission with the gimbal motors OFF. A 246 foot-pound force would be required on the engine to overcome the quiescent current (equivalent to 1.53 g) in the clutches. The gimbal motors will be turned on, prior to jettisoning the launch escape tower, to support the SPS abort criteria after the launch escape tower has been jettisoned, and will be turned OFF as soon as possible to reduce the heat problem that occurs due to the gimbal motors driving the clutch housings. With quiescent current applied, it creates a friction force in the clutch housing that creates heat, which if allowed to rise to a high temperature the electro-magnet would lose its magnetism capability; thus rendering that set of clutches inoperative. This problem occurs only during boost, not during the normal SPS burns.

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Prior to any thrusting periods the thumbwheels on panel 6 can be used to position the engine. The thrust-on signal may be provided by the G&N through the SCS, or by SCS only. In either mode the current input required (to maintain the engine thrust vector through the center of mass) to the clutches will increase above the quiescent current which increases the current in the electro-magnets that are rotating with the clutch housings. The dry powder magnetic particles have the ability to become magnetized very readily as well as becoming demagnetized as readily. The magnetic particles increase the friction force between the rotating housing and the flywheel, causing the flywheel to rotate. The flywheel arrangement is attached to the clutch output shaft allowing the clutch shaft to drive the bull gear. The bull gear drives a ball nut which drives the actuator jack-shaft to an extend or retract position, depending upon which clutch housing electro-magnet the current input is supplied to. The larger the excitation current, the higher the clutch shaft rotation rate.

Meshed with the ball nut pinion gear are two rate transducers of the tachometer type. When the ball nut is rotated, the rate transducer supplies a feedback into the summing network of the thrust vector control logic to control the driving rates of the jackscrew (acting as a dynamic brake to prevent over or undercorrecting), one transducer for each system.

The jackscrew contains four position transducers, all arranged for linear motion and all connected to a single yoke. One of the position transducers is used to provide a feedback to the summing network of transducer feedback. The two feedbacks to the summing network reduce the output current to the clutch, resulting in a proportional rate change to the desired gimbal angle position and returns to a quiescent current.

One position transducer provides a signal to the visual display on panel 6. One of the position transducers provides a feedback to the redundant summing network of the thrust vector logic for the redundant clutches. The remaining position transducer is not presently utilized.

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The spacecraft desired motion, thumbwheel positioning, engine nozzle position, thrust vector position, gimbal position display indicator and actuator ram movement is identified in figure 2.4-5.

A snubbing device provides a hard stop for an additional 1-degree travel beyond the normal gimbal limits.

Manual thrust vector control may be obtained by the crew placing the translation control clockwise. This will open contacts K10 and K13 and close contacts K11 and K14, allowing the rotation control to provide the crew with manual thrust vector control.

2.4.2.10 Propellant Utilization and Gauging Subsystem (PUGS).

The subsystem consists of eight propellant quantity sensors, a propellant utilization valve, a control unit, and a display unit (figures 2.4-6 and 2.4-7).

2.4.2.10.1 Quantity Sensing, Computing, and Indicating System.

Propellant quantity is measured by two separate sensing systems: primary and auxiliary. The primary quantity sensors are cylindrical capacitance probes, mounted axially in each tank. In the oxidizer tanks, the probes consist of a pair of concentric electrodes with oxidizer used as the dielectric. In the fuel tanks, a pyrex glass probe, coated with silver on the inside, is used as one conductor of the capacitor. Fuel on the outside of the probe is the other conductor. The pyrex glass itself forms the dielectric. The auxiliary system utilizes point sensors mounted at intervals along the primary probes to provide a step function impedance change when the liquid level passes their location centerline.

Primary propellant measurement is accomplished by the probes capacitance being a linear function of propellant height.

Auxiliary propellant measurement is accomplished by locating the propellant level with point sensors. Each point sensor consists of concentric metal rings, seven in the storage tanks and eight in the sump tanks. The rings present a variable impedance, depending on whether they are covered or uncovered by the propellants. When the propellants are between point sensors, the propellants remaining are integrated by a rate flow generator which integrates the servos at a rate proportional to the normal flow rate of the fuel and oxidizer. A mode selector senses when the propellant crosses a sensor and changes the auxiliary servos from the flow rate generator mode to the position mode, the system moves to the location specified by the digital-to-analog converter for 3/4 second to correct for any difference. The system then returns to the flow rate generator mode until the next point sensor is reached. Figures 2.4-8 and 2.4-9 illustrate point sensor locations that are covered by propellants. The nonsequential pattern detector functions to detect false or faulty sensor signals. If a sensor has failed, the information from that sensor is blocked from the system, preventing disruption of system computation.

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S/C MOTION DESIRED BY THE CREW	THUMB WHEEL POSITIONED ON PANEL ASSEMBLY 6 TO A	ENGINE NOZZLE MOVES TOWARDS THE	THE THRUST VECTOR OF THE ENGINE MOVES TOWARDS THE	GIMBAL POSITION INDICATOR ON PANEL ASSEMBLY 6 MOVES TO A	ACTUATOR RAM
S/C NOSE DOWN (PITCH)	+ NUMERAL (UP)	+ Z AXIS OF THE S/C	- Z AXIS OF THE S/C	+ NUMERAL	PITCH EXTENDS
S/C NOSE UP (PITCH)	- NUMERAL (DOWN)	- Z AXIS OF THE S/C	+ Z AXIS OF THE S/C	- NUMERAL	PITCH RETRACTS
S/C RIGHT (YAW)	- NUMERAL (RIGHT)	+ Y AXIS OF THE S/C	- Y AXIS OF THE S/C	- NUMERAL	YAW RETRACTS
S/C LEFT (YAW)	+ NUMERAL (LEFT)	- Y AXIS OF THE S/C	+ Y AXIS OF THE S/C	+ NUMERAL	YAW EXTENDS

THE ACTUATOR NULL POSITION IN YAW IS 4° OFFSET FROM THE S/C X AXIS DUE TO THE ENGINE MOUNTING PADS IN THE SERVICE MODULE BEING CANTED (BLOCK 1 VEHICLES) THE THRUST VECTOR IS 4° TO THE +Y AXIS OF THE S/C AND THE ENGINE NOZZLE IS 4° TO THE -Y AXIS OF THE S/C.

AS A RESULT THE GIMBAL POSITION INDICATOR ON PANEL ASSEMBLY 6 WILL INDICATE A +4° WHEN THE ACTUATORS ARE IN THE NULL POSITION.

TO PARALLEL THE THRUST VECTOR AND THE ENGINE NOZZLE WITH THE X AXIS OF THE S/C, THE YAW THUMB WHEEL ON PANEL ASSEMBLY 6 MUST BE POSITIONED TO 0° AND AS A RESULT THE YAW POSITION INDICATOR ON PANEL ASSEMBLY 6 WILL INDICATE 0°.

IN THIS CASE, THE YAW ACTUATOR IS NO LONGER IN ITS NULL POSITION IN RESPECT TO THE GIMBAL RING.

THE THRUST VECTOR AND THE ENGINE NOZZLE ARE NOW PARALLEL TO THE X AXIS OF THE S/C

THE ACTUATOR NULL POSITION IN PITCH IS 0° (BLOCK 1 VEHICLES).



Figure 2.4-5. Gimbaling of the Service Propulsion Engine

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When a THRUST-ON signal is provided with the SENSOR select switch in the PRIMARY or NORMAL position, the crew display digital readouts, and unbalance display will not change for  $4.5 \pm 1.0$  seconds to allow for propellant settling. However, TLM will receive the same signal as upon completion of the last firing after approximately one second of SPS THRUST-ON.

When the THRUST-ON signal is provided with the SENSOR select switch in AUXILIARY position, the crew display digital readouts and TLM will receive a change in information immediately which is generated from a flow rate integrator that simulates the nominal flow rate and transmits this as quantity information to the crew displays and TLM. The crew digital readouts, unbalance display, and TLM will not be updated to the propellant from a point sensor for  $4.5 \pm 1.0$  seconds after THRUST-ON. When the THRUST-ON signal is provided plus  $4.5 \pm 1.0$  seconds, if a point sensor is uncovered the crew digital readouts, unbalance display, and TLM will be updated to the propellant remaining at that point sensor. The time delay of  $4.5 \pm 1.0$  seconds is to the point sensor system and not to the auxiliary fuel and oxidizer servos, and is to allow for propellant settling.

Any deviation from the nominal oxidizer to fuel ratio (2:1 by mass) is displayed in pounds by the UNBALANCE indicator. The upper half of the indicator is marked INC, and the lower half is marked DEC to identify the required change in oxidizer flow rate to correct any unbalance condition.

When the SENSOR select switch is in the NORMAL position, the outputs of both sensor systems are continually compared in the comparator network. If a discrepancy occurs between total primary and total auxiliary fuel of 300 pounds, or a discrepancy between total primary oxidizer and auxiliary oxidizer of 300 pounds, the caution and warning indicator on panel 11 is illuminated. The output of the oxidizer sump tank servo amplifier and the primary potentiometer of the unbalance indicator are compared in the comparator network, and if 300 pounds or 90 percent of the critical unbalance indicated versus time remaining is reached (figure 2.4-10), the caution and warning light on panel 11 is illuminated.

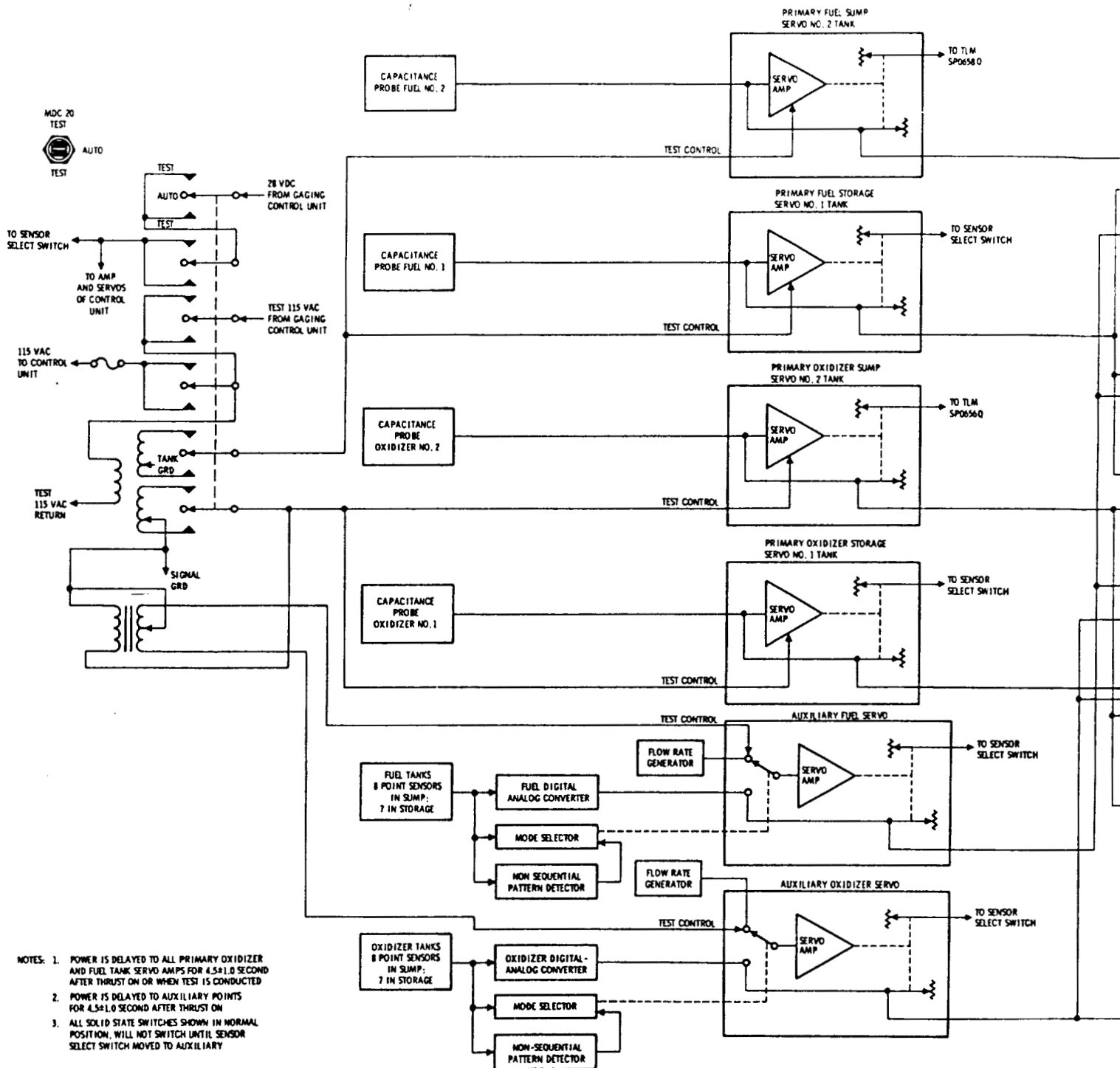
With the SENSOR select switch in the PRIMARY position, the output of the oxidizer sump tank servo amplifier and the output of the primary potentiometer in the unbalance meter are compared in the comparator network and if 300 pounds or 90 percent of the critical unbalance indicated versus time remaining is reached, the caution and warning light on panel 11 is illuminated.

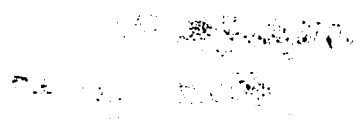
With the SENSOR select switch in the AUXILIARY position, the output of the auxiliary oxidizer servo amplifier and the output of the auxiliary potentiometer are compared in the comparator network, and if 300 pounds or 90 percent of the critical unbalance indicated versus time remaining is reached (figure 2.4-10), the caution and warning light on panel 11 is illuminated.

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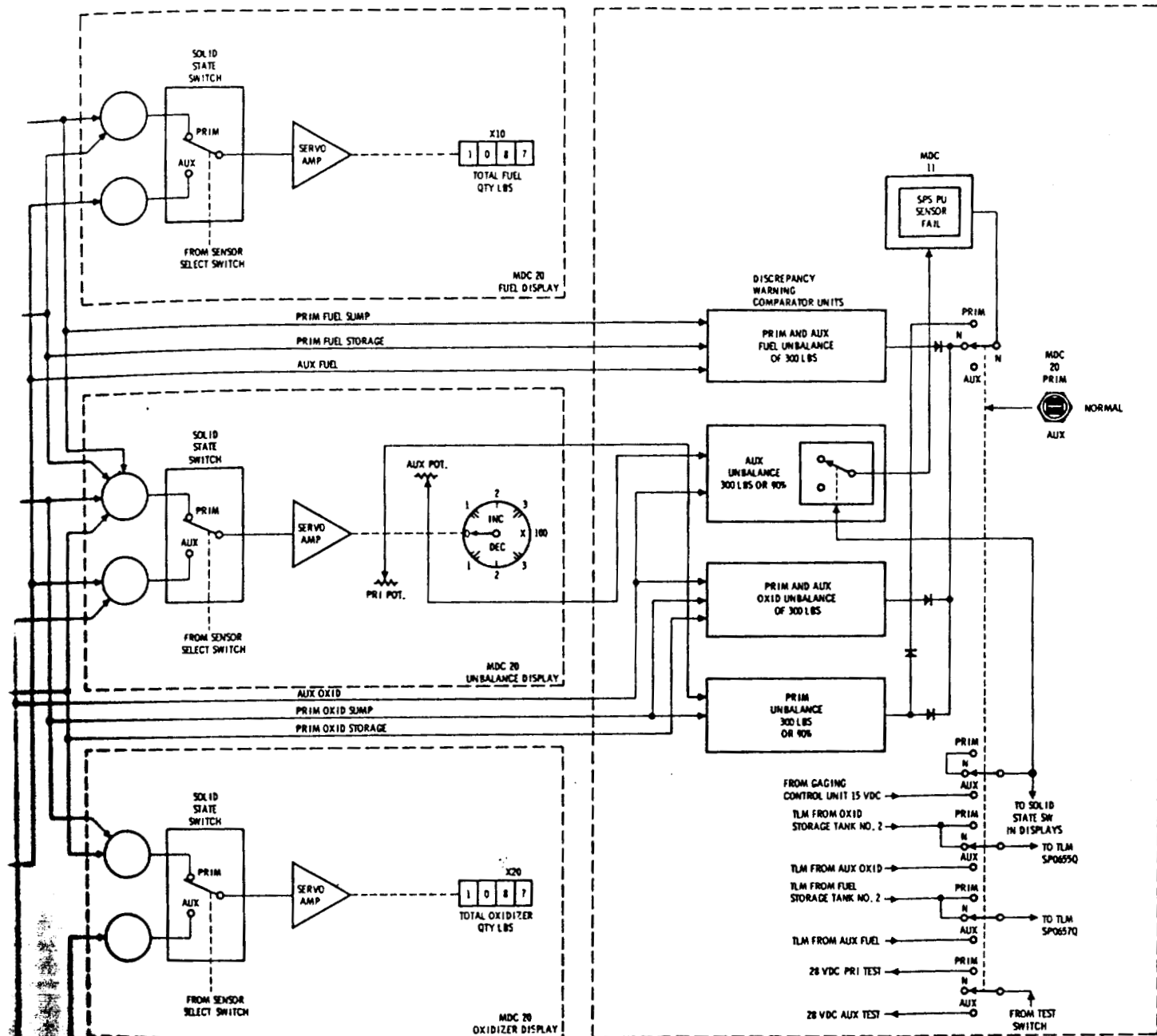
# SPS QUANTITY SENSING, COMPUTING







# IG AND INDICATING SYSTEM



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Figure 2.4-6. SPS Quantity Sensing, Computing and Indicating System

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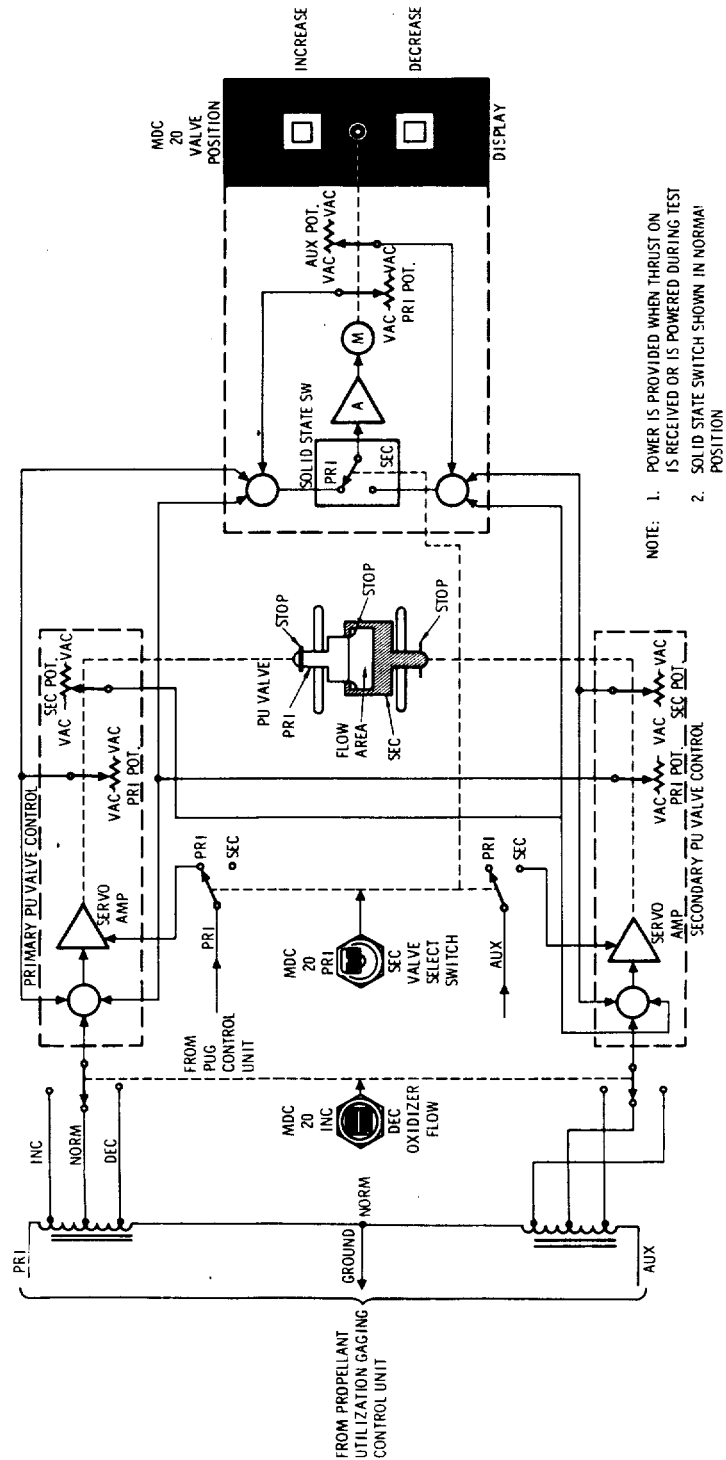
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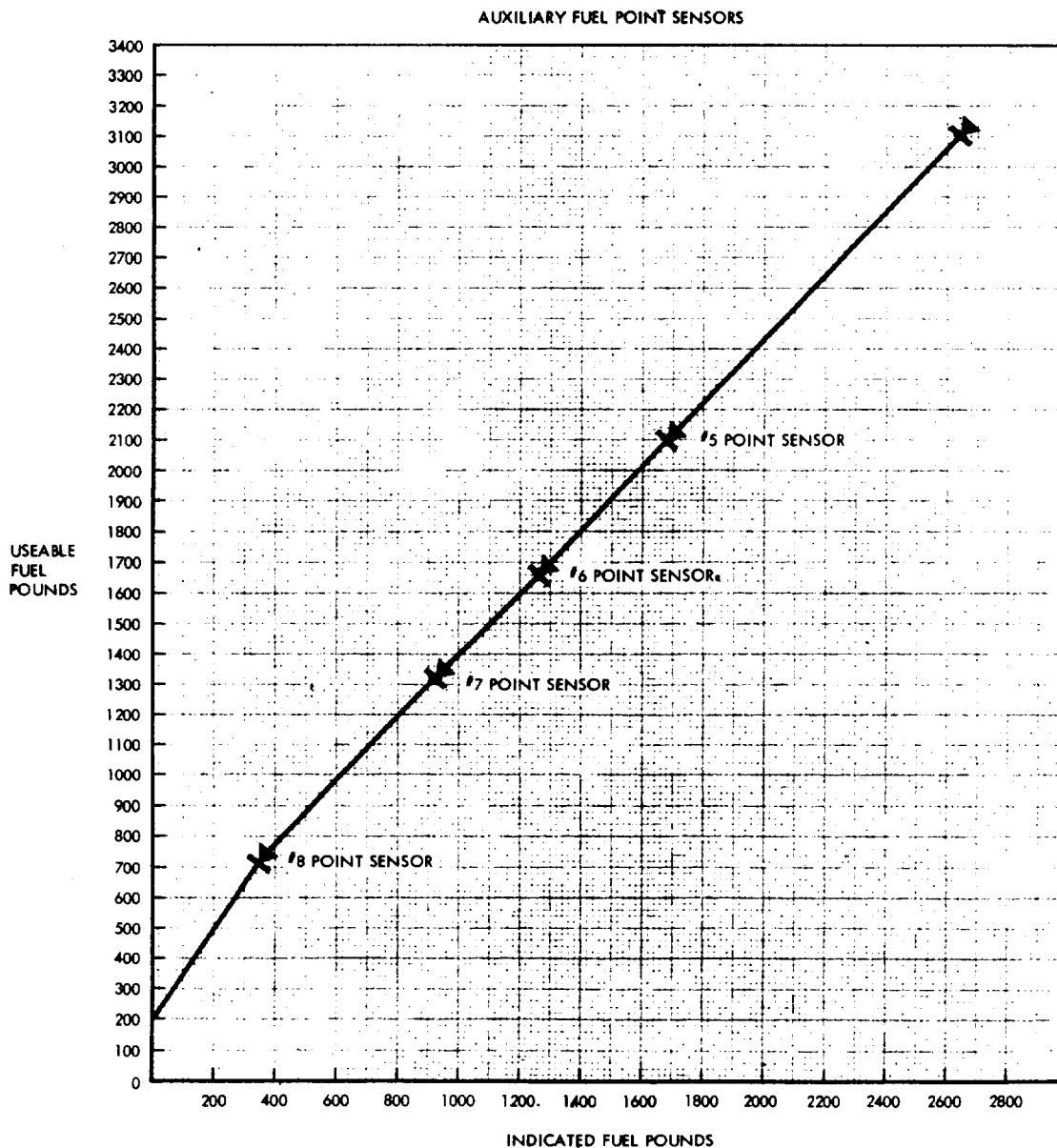
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Figure 2.4-7. Propellant Utilization Valve Control and Flag Display

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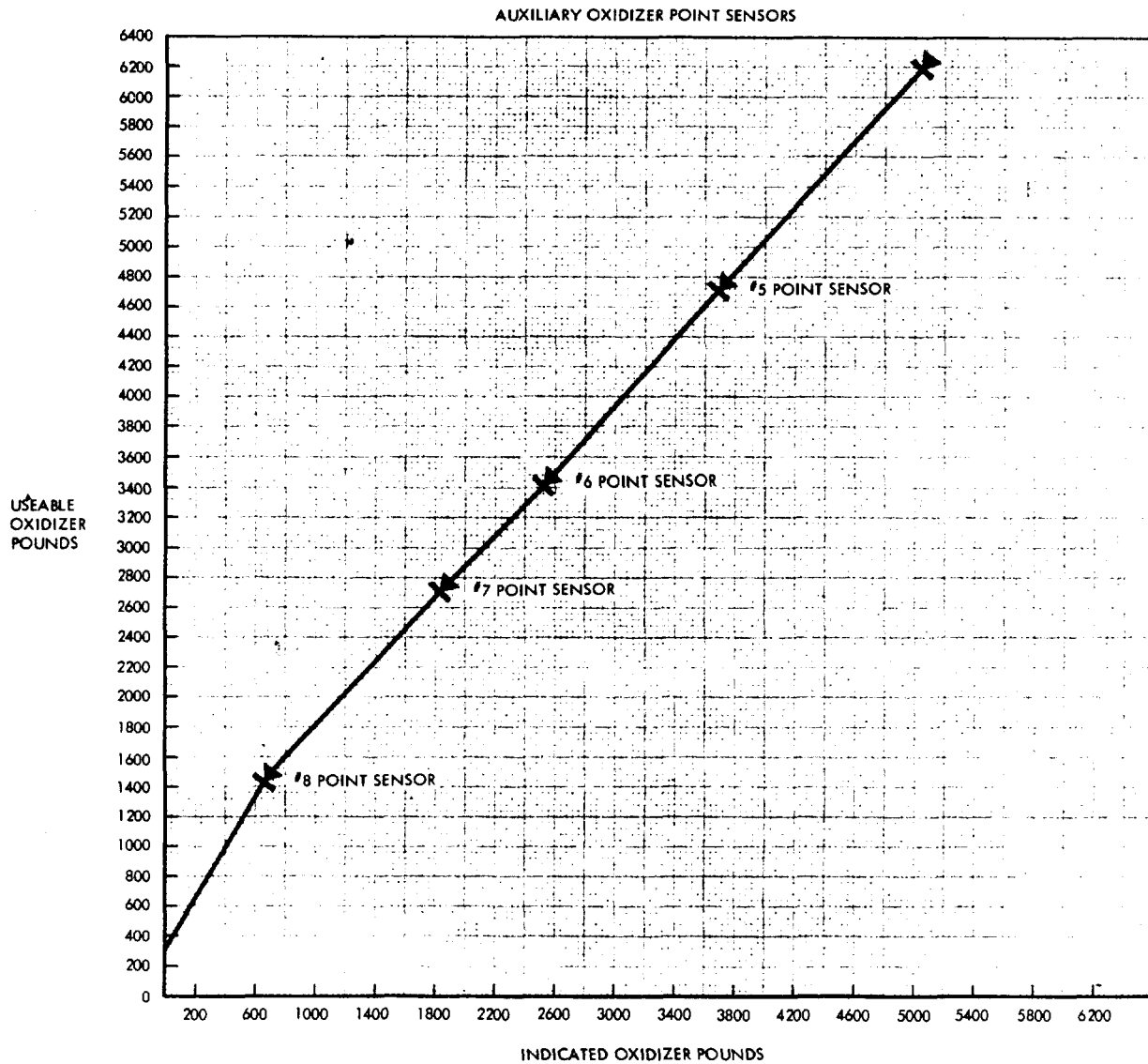


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Figure 2.4-8. Auxiliary Fuel Point Sensors

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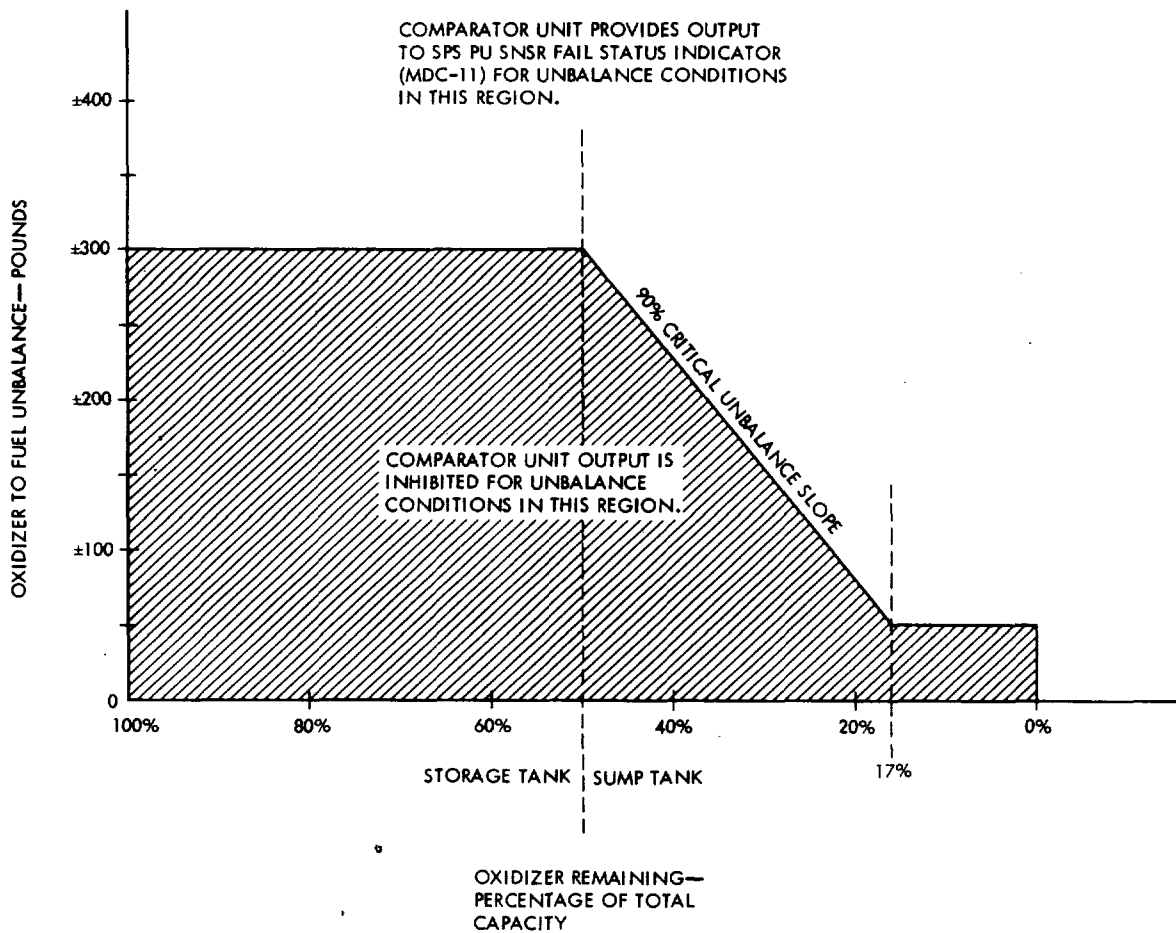
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Figure 2.4-9. Auxiliary Oxidizer Point Sensors

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Figure 2.4-10. Propellant Unbalance Warning System Output Chart

Once the warning light is illuminated, the crew can determine whether there is a malfunction within the quantity and indicating systems or if there is a true unbalance condition existing by use of the self-test portion of the system. By observing the response of each system in conjunction with the TEST switch on panel 20, the crew can recognize the malfunction or determine if there is a true unbalance existing.

#### 2.4.2.10.2 Quantity Computing and Indicating System Test.

A test of the sensing systems excluding the point sensors and probes can be implemented during THRUST-ON or -OFF periods.

With the SENSOR select switch in PRIMARY and the TEST switch in the TEST UP position, the test stimuli is applied to the primary system tank servo amplifiers after a  $4.5 \pm 1.0$  second delay. At this time, the test stimuli will drive the fuel and oxidizer displays to an increase reading at

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different rates (oxidizer at a rate of approximately 3 digits per second and fuel at a rate of approximately 1.5 digits per second), resulting in an unbalance and indicated on the unbalance display as an INC (clockwise rotation). TLM would receive an increase in propellant quantity from the primary system simultaneously.

Placing the TEST switch in the TEST DOWN position, and after a  $4.5 \pm 1.0$ -second delay, will provide test stimuli to the tank servo amplifiers which will drive the fuel and oxidizer displays to a decrease reading, returning the crew displays close to the reading displayed prior to TEST UP, simultaneously TLM would receive a decrease in propellant quantity. If the TEST switch was again placed to TEST DOWN, after a  $4.5 \pm 1.0$ -second delay, the fuel and oxidizer crew display readouts would drive to a decrease reading at different rates resulting in an unbalance and indicated on the unbalance display as a DEC (counterclockwise rotation). TLM would receive a decrease in propellant quantity simultaneously. To return to the reading displayed prior to the second TEST DOWN, place the TEST switch to TEST UP and after a  $4.5 \pm 1.0$ -second delay, the crew displays would return close to the original displayed readings, simultaneously TLM receives an increase in propellant quantity.

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To test the auxiliary system, place the SENSOR select switch to AUXILIARY and utilize the TEST switch up and down positions. There is no time delay involved with the auxiliary system.

The AUTO position removes the electrical test stimuli inputs.

2.4.2.10.3 Propellant Utilization Valve.

If an unbalance condition exists, the crew will use the propellant utilization valve to return the propellants to a balanced condition. The propellant utilization valve housing contains two sliding gate valves within the housing. One of the sliding gate valves is the primary and the remaining is the secondary (figure 2.4-7).

Stops are provided within the valve housing for the full increase or decrease positions of the primary and secondary sliding gate valves.

The secondary propellant utilization valve has twice the travel of the primary propellant utilization valve to compensate for primary propellant utilization valve failure in any position. The secondary valve is selected by the VALVE switch and is controlled by the OXIDIZER FLOW switch in the same manner as the primary.

The propellant utilization valve controls are on panel 20. The VALVE switch selects the primary or secondary propellant utilization valve. Normal position of the VALVE switch is PRIMARY. The OXIDIZER FLOW switch is utilized to position the primary or secondary propellant utilization

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sliding gate valve. When the OXIDIZER FLOW switch is in NORMAL, the sliding gate valve is in the nominal flow position and the upper and lower OXID flow position indicator is gray. When the OXIDIZER FLOW switch is placed to the INCREASE position, the sliding gate valve is in the increase flow position and the upper OXID flow position indicator is striped. When the OXIDIZER FLOW switch is placed to DECREASE position, the sliding gate valve is in the decrease flow position, but does not block the oxidizer flow completely and the lower OXID flow indicator is striped.

2.4.2.10.4 Engine THRUST ON-OFF Control.

Figure 2.4-1 illustrates the THRUST ON-OFF logic in the guidance and navigation delta V mode, the stabilization control system delta V mode and the manual direct mode.

The guidance and navigation is the primary delta V mode which provides the most accurate trajectory corrections. The G&N  $\Delta V$  mode of operation will require G&N gate 2 to be completely enabled. Its required inputs will be an ullage maneuver input which could be supplied by the SPS abort logic or the direct ullage pushbutton or by translation control 1 or 2 placed to the +X, which would satisfy the OR gate 3 function and the holding input after the G&N AND gate 2 is enabled which is processed through NAND gates 1 and 2, with the G&N  $\Delta V$  mode selected from the SCS control panel and the pulse train converter output of logic one commanded from the G&N computer by the crew. These inputs will enable AND gate 2 and provide the logic one input to inverter 3 which disables AND gate 6. Inverter 4 will provide a logic one signal to the solenoid drivers that provide the ground for the two sets of SPS relays. The two sets of SPS relays provide power to the following:

- a. The four solenoid control valves, which allow gaseous nitrogen pressure to be directed to four actuators that position eight of the ball valves in the injector valve assembly of the engine. This is due to INJECTOR PRE VALVE A and B being enabled.
- b. The quantity sensing and indicating system and the propellant utilization valve.
- c. The systems A and B helium pressurizing valves.
- d. When the output of the pulse converter is a logic zero, G&N AND gate 2 is disabled, which terminates a G&N  $\Delta V$  maneuver and removes ground from the two sets of SPS relays. (Manual backup of the THRUST CONTROL switch to OFF.)

The backup delta V mode, is the stabilization control system delta V mode which has limitations and restrictions that require individual consideration. The SCS  $\Delta V$  mode of operation will require enabling SCS AND gate 1 to initiate thrusting of the engine. SCS AND gate 1 has three enabling inputs: the input from OR gate 1 indicating a  $\Delta V$  mode is selected; the output from the DECA indicating a value greater than zero on the  $\Delta V$  REMAINING display; and the input from the THRUST ON pushbutton light indicator after it is processed through NAND gates 3 and 4. The one logic output from SCS AND gate 1 is inverted by INVERTER 2 to a zero logic which disables AND gate 6 and is inverted by INVERTER 4 to a logic one,

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and enables the solenoid drivers that provide ground to the two sets of SPS relays. The two sets of SPS relays provide power to the same functions as in the G&N  $\Delta V$  mode.

a. When the output of the DECA  $\Delta V$  REMAINING counter reaches zero velocity, SCS AND gate 1 is disabled. The logic output from AND gate 1 goes to zero and INVERTER 2 goes to a one logic output which enables AND gate 6 to a one logic output and the signal is inverted by INVERTER 4 to a zero logic output, and the solenoid drivers remove ground from the two sets of SPS relays terminating thrust. (Manual backup of the THRUST CONTROL switch to OFF.)

The DIRECT operating mode bypasses all electronics. The DIRECT ON position of the THRUST CONTROL switch provides power to the two sets of SPS relays, the same as in the G&N  $\Delta V$  mode of SCS  $\Delta V$  mode.

Thrust would be terminated by placing the THRUST CONTROL switch in the OFF position.

The SPS thrust control logic provides illumination of the talk-back light in the THRUST ON switch. To illuminate the light in a G&N  $\Delta V$  mode, AND gate 4 must be enabled. It has two inputs which are G&N  $\Delta V$  mode selected and the presence of a logic one output from the pulse train converter. With AND gate 4 enabled, OR gate 2 will trigger the lamp driver and illuminate the THRUST ON light. To illuminate the light in the SCS  $\Delta V$  mode, AND gate 3 must be enabled, it will also satisfy OR gate 2 and trigger the lamp driver. The SPS thrust control logic is interlocked so that AND gates 3 and 4 will never be enabled simultaneously because of the THRUST ON switch inhibited to the pulse train converter. Therefore, the THRUST ON light will be illuminated at all times when the thrust is on for normal operation. If the direct function is used to initiate thrusting, it will bypass all electronics and not illuminate the THRUST ON light.

The output from the SPS thrust control logic performs a function other than energize the fuel and oxidizer solenoid valves. It provides the logic switches required to reconfigure the SCS relays for proper thrust vector control. The thrust control switch provides both inputs to OR gate 4 if both dc buses are operational. Either dc bus will enable OR gate 5 to provide the upper input to INHIBIT AND gate 1. AND gate 5 provides the controlling input to the INHIBIT AND gate 1. When the solenoid drivers are not energized and the thrust control switch is in NORMAL, both inputs to AND gate 5 are true. The true input will maintain a logic false output from the INHIBIT AND gate 1 because of the inversion on the input of the gate. When either SPS relay set is activated by a solenoid driver or by the ground contacts of the DIRECT ON switch, AND gate 5 will be disabled by the ground or false input. The input will be inverted by the INHIBIT AND gate 1 input to enable an output to the time delay. The time delay is required to permit thrust buildup from the SPS engine before the ullage maneuver is terminated; however, the pitch and yaw attitude error inputs are inserted into the TVC electronics immediately. This action assures positive g forces

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throughout thrust initiation of the SPS engine and gimbaling control of the SPS engine for the entire thrust buildup. The time delay is also active after INHIBIT AND gate 1 is disabled by enabling AND gate 5. AND gate 5 is enabled when both sets of SPS relays are de-energized. The time delay is active for both outputs when the signal is removed to permit continued SPS engine gimbal control, while the residual thrust is present and inhibits RCS operation in pitch and yaw until residual thrust is reduced. This reduces the tumbling induced at thrust termination. The time delay is approximately one second for application and removal of the engine ignition signal.

2.4.3 PERFORMANCE AND DESIGN DATA.

2.4.3.1 Design Data.

The following list contains specific data for the components in the SPS:

HELIUM TANKS (2)	4000±50 psia fill pressure, 4400 maximum operating pressure 70°±10°F, capacity 19.4 cubic feet, inside diameter 40 in. and a wall thickness of 0.46 in.
REGULATOR UNITS (2)	Working regulator - Primary 186±4 psig, secondary 191±4 psig, primary lockup 200 psig, secondary lockup 205 psig. Normally locked by working regulator; primary 181±4 psig, secondary 191±4 psig, primary lockup 195 psig, secondary lockup 205 psig.
PRESSURE TRANS-DUCERS (2)	Fuel and oxidizer underpressure setting (SPS PRESS light, panel 11) 160 psia.
ULLAGE PRESSURE (REGULATED HELIUM)	Fuel and oxidizer overpressure setting (SPS PRESS light, panel 11) 200 psia.
PROPELLANT UTILIZATION	Increase position - 46.65 lbs/second
VALVE CONTROL (2)	Normal position - 45.27 lbs/second at 70°F and 168±4 psig  Decrease position - 43.87 lbs/second  Response time - Normal to increase or vice-versa, or normal to decrease or vice-versa is 3 to 4 seconds
QUANTITY SENSING SYSTEM ACCURACY	±0.35% of full tank plus ±0.35% of propellant remaining primary system ±0.35% of full tank plus ±0.35% of propellant remaining plus 2.3% of storage tank quantity remaining, auxiliary system.

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HELIUM RELIEF VALVE (2)	Diaphragm ruptures at $220 \pm 7$ psig Filter - 10 microns normal, 25 microns absolute  Relief valve relieves at $232 \pm 8$ psig  Relief valve reseats at 212 psig minimum  Flow capacity 3 lbs/second minimum at 60 F and 250 psig  Bleed device closes at ambient to 100 psi and is manually reset open
OXIDIZER STORAGE AND SUMP TANK	Total tank capacity 30,600 lbs, usable 27,333 lbs. Each tank has a volume of 175 cubic ft.  Fill pressure 110 psia. Ullage after filling 2.4 cubic ft in storage and 8.0 cubic ft in sump tank. Ullage after pressurized to 175 psia, 6.8 cubic ft in storage and 5.0 cubic ft in sump tank. Inside diameter 51 in., length 165.4 in., and will elongate to 0.125 in. when pressurized to 240 psi and 120°F for 336 hours. Wall thickness 0.060 in. in continuous areas, 0.069 in. weld buildup areas and 0.031 in. on domes. Fill tolerance of 1/4 of 1% of full tank plus 1/4% of propellant remaining.
FUEL STORAGE AND SUMP TANK	Total tank capacity 15,300 lbs, usable 13,677 lbs. Each tank has a volume of 139.7 cubic ft.  Fill pressure 90 psia. Ullage after filling 1.8 cubic ft in storage and 5.8 cubic ft in sump tank. Ullage after pressurized to 175 psia, 6 cubic ft in storage and 3.0 cubic ft in sump tank. Inside diameter 45 in., length 166.8 in., and will elongate to 0.125 in. when pressurized to 240 psi and 120°F for 336 hours. Wall thickness 0.053 in. in continuous areas, 0.061 in. in weld buildup areas, and 0.031 in. on domes. Fill tolerance of 1/4 of 1% full tank plus 1/4% of propellant remaining.

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NOMINAL PROPELLANT TANK WORKING PRESSURE	175±4 psia
INTERFACE FLANGE FILTER	500 microns absolute
GASEOUS NITROGEN PROPELLANT VALVE CONTROL SYSTEMS (2)	<p>Storage vessel pressure 2500±50 psi at 68°F, 2900 psi at 130°F. Support 36 valve actuations.</p> <p>Regulator, single stage, 130±7 psi at all flow up to 0.035 lbs/second.</p> <p>145 psi maximum lockup pressure.</p> <p>Relief valve - relieves at 350±10 psi, reseats at not less than 250 psi</p> <p>Ball valves 1 and 4 dry opening travel time of 0.6 (+0.2, - 0.05) second</p> <p>Ball valves 2 and 3 dry opening travel time of 0.325±0.1 second.</p> <p>Ball valves 1 and 4 dry closing travel time of 0.375±0.05 second</p> <p>Ball valves 2 and 3 dry closing travel time of 0.575±0.1 second</p>
ENGINE	<p>500-second service lift on S/C 014</p> <p>Capable of 36 restarts</p> <p>Expansion ratio, 6 to 1 at ablative chamber exit area, 62.5 to 1 at nozzle extension exit area.</p> <p>Cooling chamber, ablation and film extension, radiation</p> <p>Injector type, baffled regeneratively, cooled, unlike impingement</p> <p>Oxidizer lead, 8 deg.</p> <p>Length, 152.82 inches</p>

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Nozzle extension exit diameter, 94.4 inches

Weight, approximately 650 lbs

Ablative chamber throat temperature sensor illuminates SPS WALL TEMP HI caution and warning light on panel 11 at 380°F, one sensor per harness.

SPS  $P_c$  transducer,  $P_c$  displayed on panel 3 through L/V AOA, SPS  $P_c$  switch to L/V AOA, SPS  $P_c$  indicator, green range on indicator is 65 to 125%, normal  $P_c$  85 to 125 psia.

SPS

GIMBAL LIMITS

About Z-Z axis  $\pm 7$  (+1/2, -0) deg with additional 1 deg for snubbing yaw

About Y-Y axis  $\pm 6$  (+1/2, -0) deg with additional 1 deg for snubbing pitch

GIMBAL MOTOR UNDER  
AND OVERCURRENT  
RELAYS

Undercurrent (primary only) below 6 amperes detected for a duration of 250±50 milliseconds or more shall interrupt the flow to the load in less than 100 milliseconds.

Overcurrent dependent upon temperature during start transient and steady state of gimbal motor on primary. Secondary controlled by 70-amp circuit breaker.

ACTUATOR CLUTCHES

Quiescent current of 60 (+10, -5) milliamps (Motors off, a 246 ft-lb force required to move engine equivalent to 1.53 g.)

ACTUATOR PRESSURIZED  
S/C 012 and 014 SERVO  
ACTUATOR DEFLECTION  
RATE

3.5±1.0 psi dry air at -160°F at vendor  
0.23 radians per second (13.09° per second)

FLIGHT COMBUSTION

180 g's peak to peak for 70±20 milliseconds

STABILITY MONITOR  
SYSTEM

600 to 5000 cycles per second

2.4.3.2 Performance Data.

Refer to mission modular data book, SID 66-1177.

2.4.3.3 Power Consumption Data.

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Subsystem and Component	Control	No. of Units	Watts per Unit		Total Watts	
			AC	DC	AC	DC
Service propulsion Propellant utilization valve	VALVE sw and OXIDIZER FLOW sw (Ref. gauging sys)				62.6	16.8
Propellant utilization gauging system	Gauging CB(4) SPS GAUGING AC sw SENSOR sw					
Injector prevalues	He valve CB(2) INJECTOR PREVALVE sw (2)	2		21.0		42.0
He solenoid valves	He PRESSURIZING sw (2) SPS relay	2		28.0		56.0
Feedline heaters	SPS HEATER sw	26		(See fig- ure 2.4-2)		33.0
Pilot valves (SCS)	ECA drivers (2)	4		10.5		42.0
Gimbal actuator motors	Gimbal CB (6) GIMBAL MOTOR sw (4)	Channel I				
		Idle				
		pitch		450*	}	900
		yaw		450*		
		Boost				
		pitch		511*	}	1022
		yaw		511*		
		Thrust ON				
		pitch		775*	}	1550
		yaw		775*		
		Maximum				
		pitch		1800*	}	3600
		yaw		1800*		
		Channel II				
		Idle				
		pitch		335**	}	670
		yaw		335**		
		Boost				
		pitch		335**	}	670
		yaw		335**		
		Thrust ON				
		pitch		335**	}	670
		yaw		335**		
		Maximum				
		pitch		335**	}	670
		yaw		335**		

\*With quiescent current

\*\*Without quiescent current

Above statements assume channel I is the operating channel and channel II is standby. Channel I operating values applicable to channel II when channel II is commanded. 28-vdc supply values, current draw values not a direct function of an applied voltage.

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2.4.3.4 SPS Electrical Power Distribution.

See figure 2.4-11 for electrical power distribution.

2.4.4 OPERATION LIMITATIONS AND RESTRICTIONS.

The operational limitations and restrictions of the SPS are as follows:

a. Propellant quantity gauging subsystem is operational only during engine firing. A 4.5-second firing period is required before propellant quantity information is updated, when SENSOR switch is in the NORM or PRI position. Delay is built-in to allow propellants to settle and stabilize before updating the displays.

b. A one-second time delay between actuation of GIMBAL MOTOR switches (MDC-3) is required, as simultaneous actuation may result in an excessive power drain.

c. Engine design minimum impulse control limit is 0.4 second; however, mission minimum impulse may be longer.

d. Due to adverse temperature effects, engine gimbal drive motors should not be continuously energized for periods in excess of 12 minutes.

e. Single bank mode of operation by the bipropellant valve assembly will result in a 3 percent reduction in thrust.

2.4.5 TELEMETRY MEASUREMENTS.

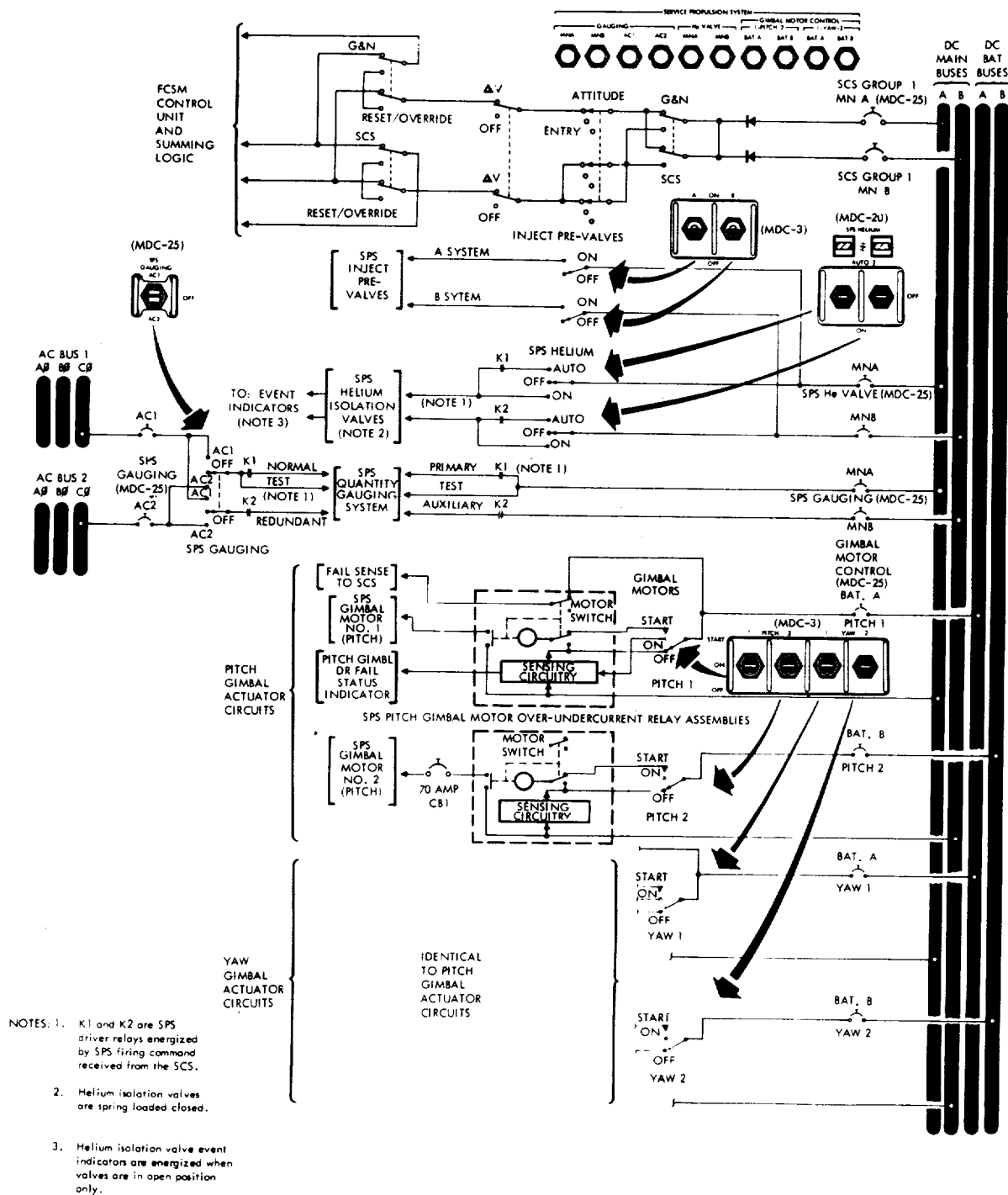
The following subsequent list is of all SPS telemetry data monitored by flight controllers and ground support personnel.

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Figure 2.4-11. SPS Electrical Power Distribution Diagram

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Crew Display	Figure	Measurement	Measure- ment Number	Range	Signal Conditioner	Channel Code*	Bit Rate*	*	Operating Range
Panel 20	2. 4-1	Helium Tank Supply Pressure	SP0001P	+0 +5K psia	S28AR3	11A66	H2	PCM	4000±50 psia and decrease with firings
Panels 20 & 11	2. 4-1	Regulated Helium Pressure to Fuel Tank	SP0006P	+0 +300 psia	S28AR6	11A70	H2	PCM	170 to 195 psia
Panels 20 & 11	2. 4-1	Regulated Helium Pressure to Oxidizer Tank	SP0003P	+0 +300 psia	S28AR5	11A68	H2	PCM	170 to 195 psia
Panels 20 & 11	2. 4-1 and 2. 4-6	Quantity Sensing System Sensor Select Switch in Normal							
		Primary Fuel Sump 2	SP0658Q	+0 +8K lbs		10A94	H1	PCM	Variable
		Primary Fuel Storage 1	SP0657Q	+0 +8K lbs		10A92	H1	PCM	
		Primary Oxidizer Sump 2	SP0656Q	+0 +16K lbs		10A90	H1	PCM	
		Primary Oxidizer Storage 1	SP0655Q	+0 +16K lbs		10A88	H1	PCM	
		Sensor Select Switch in Primary							
		Primary Fuel Sump 2	SP0658Q	+0 +8K lbs		10A94	H1	PCM	Variable
		Primary Fuel Storage 1	SP0657Q	+0 +8K lbs		10A92	H1	PCM	
		Primary Oxidizer Sump 2	SP0656Q	+0 +16K lbs		10A90	H1	PCM	
		Primary Oxidizer Storage 1	SP0655Q	+0 +16K lbs		10A88	H1	PCM	
		Sensor Select Switch in Auxiliary							
		Primary Fuel Sump 2	SP0658Q	+0 +8K lbs		10A94	H1	PCM	Variable
		Primary Oxidizer Sump 2	SP0656Q	+0 +16K lbs		10A90	H1	PCM	
		Auxiliary Fuel	SP0657Q	+0 +8K lbs		10A92	H1	PCM	
		Auxiliary Oxidizer	SP0655Q	+0 +16K lbs		10A88	H1	PCM	
	2. 4-1	Temperature 1 Oxidizer Distri- bution Line	SP0054T	+0 +200°F					
	2. 4-1	Temperature 2 Oxidizer Distri- bution Line	SP0055T	+0 +200°F					
	2. 4-1	Temperature 1 Fuel Distribution Line	SP0057T	+0 +200°F					
	2. 4-1	Temperature 2 Fuel Distribution Line	SP0058T	+0 +200°F					
Panel 20	2. 4-1	Fuel Inlet Pressure to Fuel Valve	SP0010P	+0 +300 psia	S28AR8	11A77	H2	PCM	135 to 195 psia
Panel 20	2. 4-1	Oxidizer Inlet Pressure to Oxidizer Valve	SP0009P	+0 +300 psia	S28AR7	11A76	H2	PCM	135 to 195 psia
Panel 3	2. 4-1	Chamber Pressure	SP0061P	+0 +150 psia	S28AR9	12A11	H1	PCM	65 to 125 psia
	2. 4-1	Injector Temperature	SP0060T	+0 +200°F		11A109	H1	FQ	Variable
Panel 20	2. 4-1	Primary Gaseous Nitrogen Tank Supply Pressure	SP0600P	+0 +5000 psia	S28AR41	10A78	H1	PCM	2500±50 psia and decrease with firings
Panel 20	2. 4-1	Secondary Gaseous Nitrogen Tank Supply Pressure	SP0601P	+0 +5000 psia	S28AR42	11A125	H1	PCM	2500±50 psia and decrease with firings
Panel 20	2. 4-1	Ball Valve Position 1	SP0022H	+0 +90 deg		11A103	H1	PCM	Open or closed
Panel 20	2. 4-1	Ball Valve Position 2	SP0023H	+0 +90 deg		11A105	H1	PCM	Open or closed
Panel 20	2. 4-1	Ball Valve Position 3	SP0024H	+0 +90 deg		11A110	H1	PCM	Open or closed

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Crew Display	Figure	Measurement	Measure- ment Number	Range	Signal Conditioner	Channel Code*	Bit Rate*	*	Operating Range
Panel 20	2.4-1 2.4-1	Ball Valve Position 4 Temperature Oxidizer Engine Feed Line	SP0025H SP0049T	+0 +90 deg +0 +200°F		11A111	H1	PCM	Open or closed Variable
Panel 20	2.4-1	Temperature Fuel Engine Feed Line	SP0048T	+0 +200°F					+40 to +120°F
Panel 11	2.4-1	Temperature Engine Valve Body	SP0045T	+0 +200°F					Variable
	2.4-1	Temperature Combustion Chamber Outer Skin 1	SP0020T	+0 +500°F	Collins C28-1A5	10A84	H1	PCM	Illuminates C&W
	2.4-1	Temperature Nozzle Outer Skin 1	SP0050T	-260 +2500°F	S28AR60	10A85	H1	PCM	light at 380°F
		Pitch Actuator Case Temperature	SP2055T	+0 +200°F		10A68	H1	FQ	Variable
		Yaw Actuator Case Temperature	SP2054T	+0 +200°F		11A119	H1	FQ	Variable
		SPS Solenoid Driver Out 1	CH4320X			51E-09	E1	PCME	Variable
		SPS Solenoid Driver Out 2	CH4321X			51E-10	E1	PCME	Event
		Yaw Position Feedback	CH1034H	-8.5 +8.5 vdc		51A 7	H1	PCM	Variable
		Pitch Position Feedback	CH0034H	-6 +6 vdc		51A3	H1	PCM	Variable

\*Analog measurements digitally coded into 8 bit words

Analog measurements - 0 to 5 vdc

FQ - Flight qualification measurements

H1 - High bit rate

H2 - High and low bit rate

E1 - High bit rate

Channel code example: 10A68

Significant number - 1

How many zeros } 1 sample  
after most significant } per  
number is amount of } second  
samples per second. } 0

Analog - A

Event - E

Channel Code - 68

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SECTION 2

SUBSECTION 2.5

REACTION CONTROL SYSTEM (RCS)

2.5.1 INTRODUCTION.

The Apollo command service module consists of two separate reaction control systems, completely independent, designated S/M RCS and C/M RCS. The S/M RCS is utilized to control S/C rotation in all three axes, in addition to any minor translation requirements including S-IVB separation, SPS ullage, and C/M-S/M separation maneuvers. The C/M RCS is utilized to control C/M rotation in all three axes after C/M-S/M separation and during entry maneuvers. The C/M RCS does not have translation capabilities.

RCS

Both the S/M and C/M RCS are controlled either automatically or manually from the command module. Physical location of the RCS engines is shown in figure 2.5-1. Engine firing sequence for specific maneuvers and individual engine circuit breaker power control are shown in figure 2.5-2.

2.5.2 S/M RCS FUNCTIONAL DESCRIPTION.

The S/M RCS consists of four individual, functionally identical packages, located 90 degrees apart around the forward portion (+X-axis) of the S/M periphery and offset from the S/C Y- and Z-axes by 7 degrees 15 minutes. Each package configuration, called a quad, is such that the reaction engines are mounted on the outer surface of the panel and the remaining components are inside. Propellant distribution lines are routed through the panel skin to facilitate propellant transfer to the reaction engine combustion chambers. The engine combustion chambers are canted approximately 10 degrees away from the panel structure to reduce the effects of exhaust gas on the service module skin. The two roll engines on each quad are offset-mounted to accommodate plumbing in the engine mounting structure.

Each RCS package incorporates a pressure-fed, positive-expulsion, pulse-modulated, bipropellant system to produce the reaction thrust required to perform the various S/M RCS control functions. Acceptable package operating temperature is maintained by internally mounted, thermostatically controlled electric heaters. The S/M RCS propellants consist of nitrogen tetroxide ( $N_2O_4$ ), used as the oxidizer; mono-methylhydrazine (MMH) used as the fuel. Pressurized helium gas is the propellant transferring agent.

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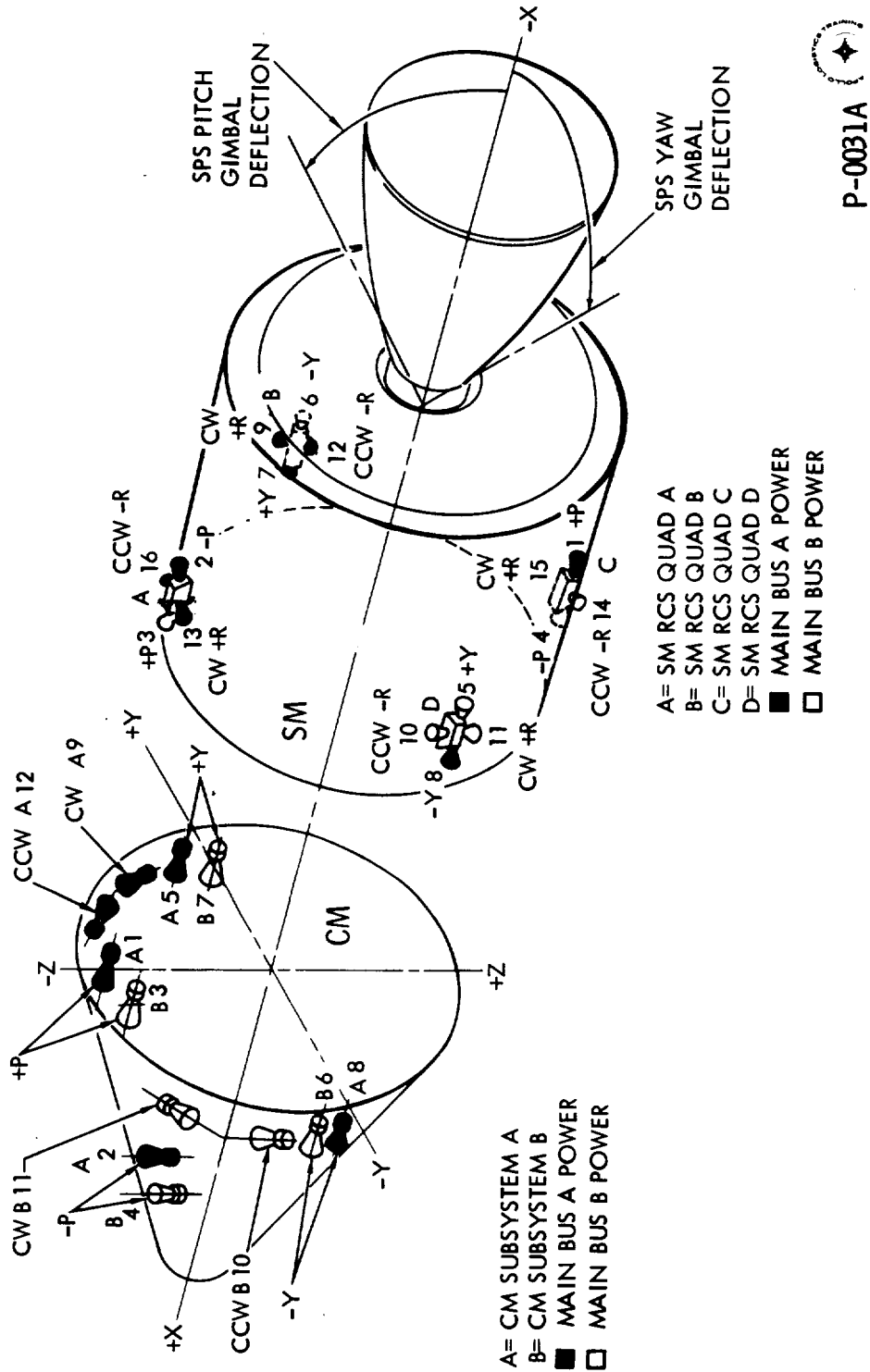


Figure 2.5-1. C/M-S/M Engine Locations

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BUS POWER	CIRCUIT BREAKER	SM ENGINE			CM ENGINE			SM ENGINE UTILIZATION FOR CHANNEL SWITCHES							
		QUAD	MANUEVER	SCS NO.	PROP NO.	SYSTEM	MANUEVER	SCS NO.	PROP NO.	-X	+X	-Y	+Y	-Z	+Z
MN A	SCS MN A 1 PITCH	C	+P	1	S19A383	A	+P	1	C19B7		1				PITCH
	C15A6CB40 PANEL 25	A	-P	2	S19A183	A	-P	2	C19B11		2				
	SCS MN A 1 YAW	B	+Y	7	S19A283	A	+Y	5	C19B9	7					YAW
	C15A6CB32 PANEL 25	D	-Y	8	S19A483	A	-Y	8	C19B1	8					
	SCS MN A B&D ROLL	B	CW+R	9	S19A382	A	CW+R	9	C19B5						B&D ROLL
	C15A6CB34 PANEL 25	B	CCW-R	12	S19A284	A	CCW-R	12	C19B3					12	
	SCS MN A A&C ROLL	A	CW+R	16	S19A182		DEADFACED AT CM SM SEPARATION OR LES ABORT					16	13		A&C ROLL
	C15A6CB36 PANEL 25	A	CW+R	13	S19A184										
	SCS MN B 2 PITCH	C	+P	4	S19A381	B	+P	4	C19B12	4					PITCH
	C15A6CB39 PANEL 25	A	-P	3	S19A181	B	-P	3	C19B8	3					
	SCS MN B 2 YAW	B	-Y	6	S19A281	B	-Y	6	C19B2		6				YAW
	C15A6CB31 PANEL 25	D	+Y	5	S19A481	B	+Y	7	C19B10		5				
MN B	SCS MN B B&D ROLL	D	CCW-R	10	S19A484	B	CCW-R	10	C19B4					10	B&D ROLL
	C15A6CB33 PANEL 25	D	CW+R	11	S19A482	B	CW+R	11	C19B6					11	
	SCS MN B A&C ROLL	C	CCW-R	14	S19A382		DEADFACED AT CM SM SEPARATION OR LES ABORT					14	15		A&C ROLL
	C15A6CB35 PANEL 25	C	CW+R	15	S19A384										
	SCS MN A DIRECT CONTROL C15A6CB42 PANEL 25	C	+P	1	S19A383	A	+P	1	C19B7	8	1				
		D	-Y	8	S19A483	A	-Y	8	C19B1	7					
		B	+Y	7	S19A283	A	+Y	5	C19B9						
		A	CCW-R	16	S19A182		DEADFACED AT CM SM SEPARATION AND LES ABORTS								
		B	CCW-R	12	S19A284	A	CCW-R	12	C19B3						
		B	CW+R	9	S19A282	A	CW+R	9	C19B5						
		A	CW+R	13	S19A184		DEADFACED AT CM SM SEPARATION AND LES ABORTS								
		C	CW+R	15	S19A384										
MN B	SCS MN B DIRECT CONTROL C15A6CB41 PANEL 25	A	-P	2	S19A183	A	-P	2	C19B11		2				DIRECT RCS SWITCH PANEL 8
		C	+P	4	S19A381	B	+P	4	C19B12	4					
		A	+P	3	S19A181	B	+P	3	C19B8	3					
		B	-Y	6	S19A281	B	-Y	6	C19B2		6				
		D	+Y	5	S19A481	B	+Y	7	C19B10		5				
		D	CCW-R	10	S19A484	B	CCW-R	10	C19B4						
		C	CCW-R	14	S19A382		DEADFACED AT CM SM SEPARATION AND LES ABORTS								
		D	CW+R	11	S19A482	B	CW+R	11	C19B6						

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Figure 2.5-2. S/M-C/M RCS Engine Power Supplies



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The reaction engines may be pulse-fired, producing short-thrust impulses or continuously fired, producing a steady-state thrust level. The short-pulse firing permits attitude-hold modes of operation and extremely accurate attitude alignment maneuvers during navigational sightings. CSM attitude control is normally maintained by utilizing the applicable pitch, yaw, and roll engines on all four quads. However, in the event of a malfunction, complete attitude control can be maintained with only two adjacent quads operating. This two-quad capability does not include the execution of translation and ullage maneuvers.

A functional flow diagram of one S/M RCS quad is shown in figure 2.5-3. The helium storage vessel supplies pressure to two solenoid-operated helium isolation valves that are normally open throughout the mission. This allows helium pressure to the pressure regulators downstream of each helium isolation valve reducing the high-pressure helium to a desired working pressure.

Regulated helium pressure is directed through a series parallel combination of four independent check valves. The check valves permit helium pressure to the fuel and oxidizer tanks and prevent reverse flow of propellant vapors or liquid. A pressure-relief valve is installed in the pressure lines between the check valves and propellant tanks to protect the propellant tanks from any excessive pressure increase.

Helium entering the propellant tanks creates a pressure buildup around the propellant positive expulsion bladders forcing the propellants to be expelled into the propellant distribution lines. Propellants then flow through the normally open propellant isolation valves.

Oxidizer and fuel is distributed to the eight fuel and oxidizer injector valves by a parallel feed system. The fuel valve on each engine opens 2 milliseconds prior to the oxidizer valve to obtain proper engine operation. Each valve assembly contains orifices which meter the propellant flow to obtain a nominal 2:1 oxidizer/fuel ratio by weight. The oxidizer and fuel impinge, atomize, and ignition due to the hypergolic propellants. The injector valves are controlled automatically by the G&N system or the SCS. Manual override direct control is provided for rotational maneuvers and direct ullage only. The injector valves are spring-loaded closed. This system configuration maintains propellants under constant pressure at the engine injector valves providing rapid consistent response rates to thrust on-off commands.

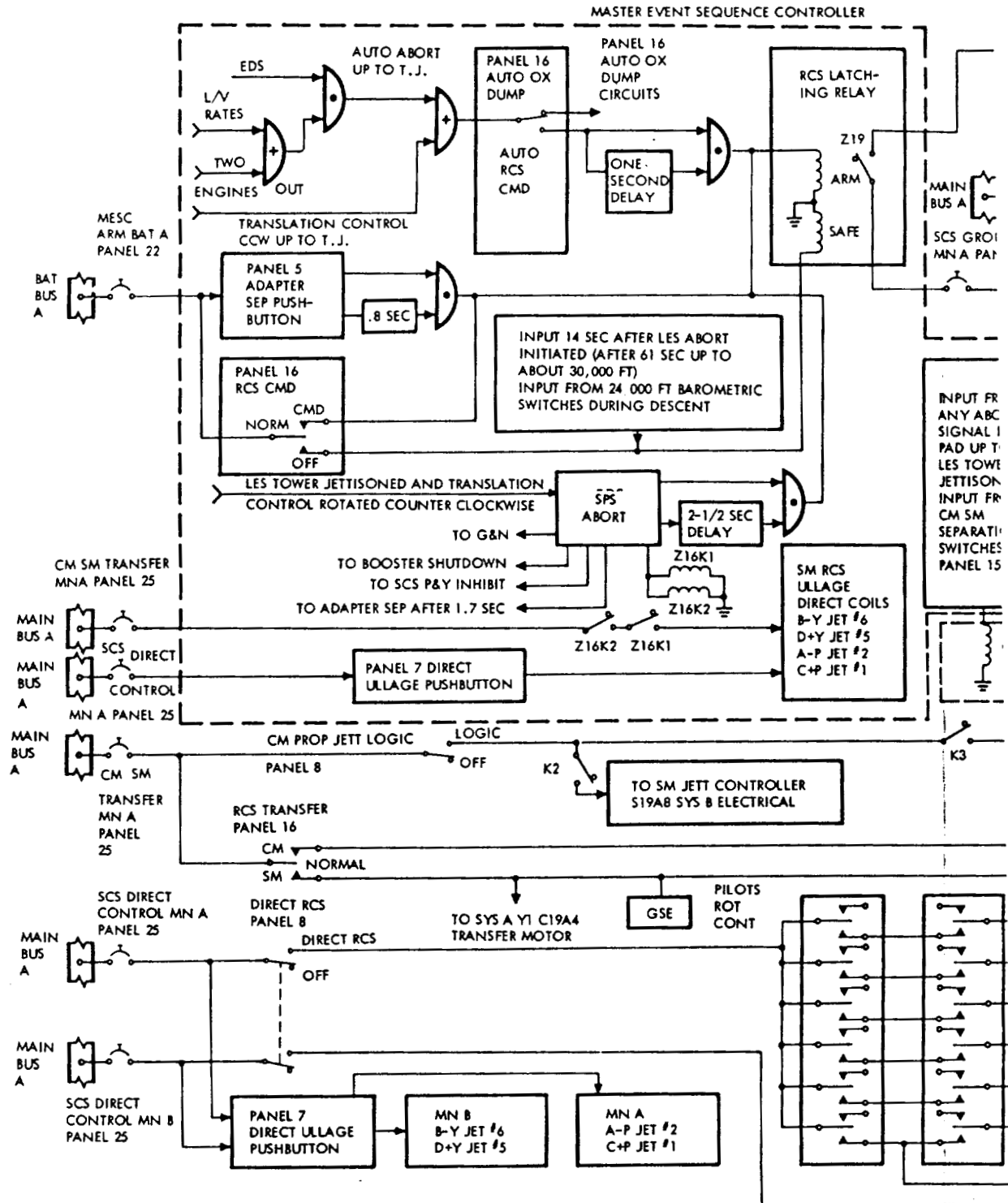
2.5.3 S/M RCS MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

The S/M RCS is composed of four separate, individual packages; each package containing the following five major subsystems:

- Pressurization
- Propellant
- Rocket engine

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REACTION CONTROL SYSTEM

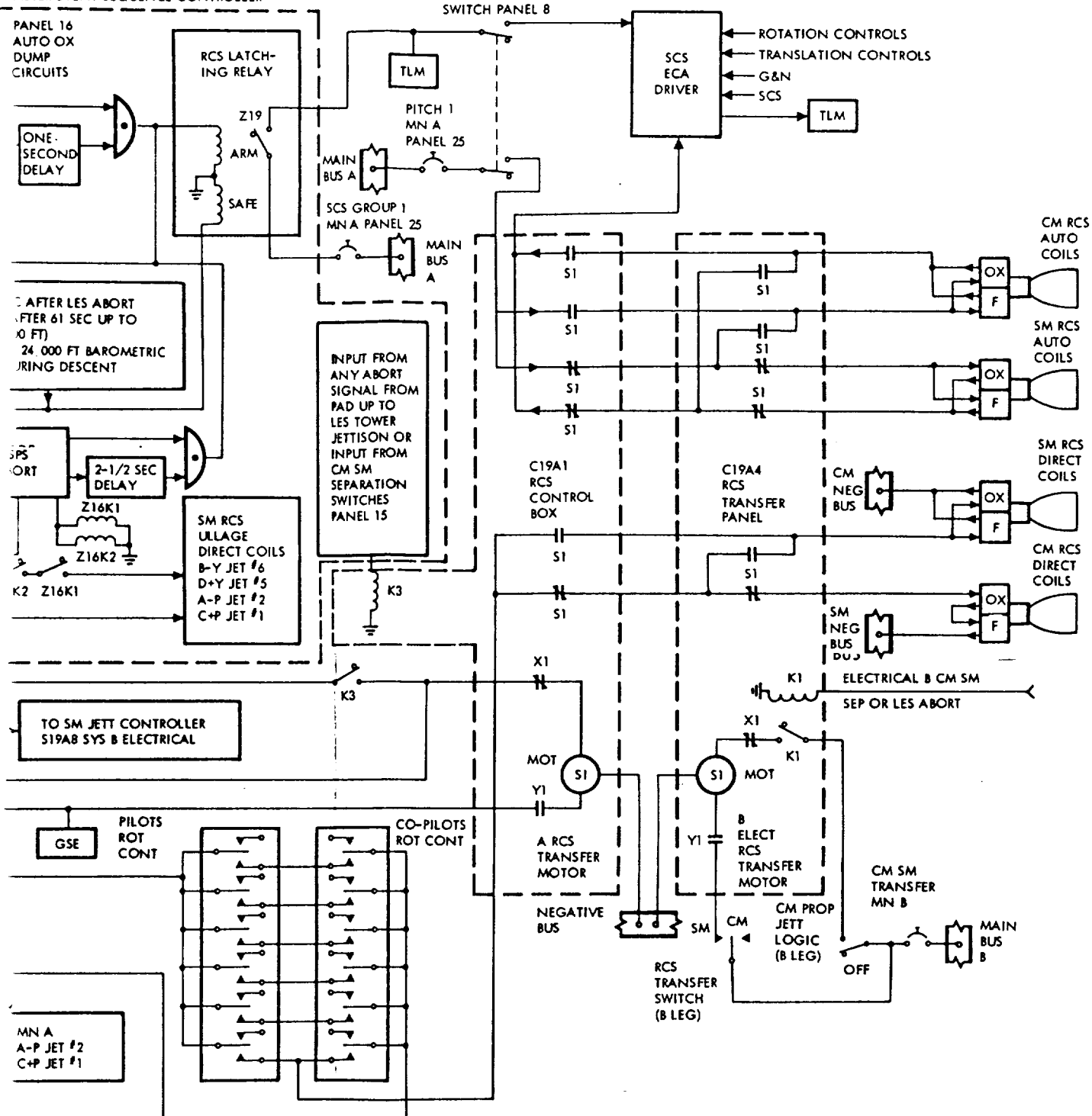


**SOLDOUT FRAME**

2.

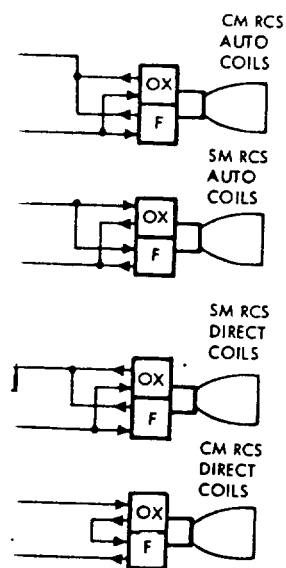


# MASTER EVENT SEQUENCE CONTROLLER

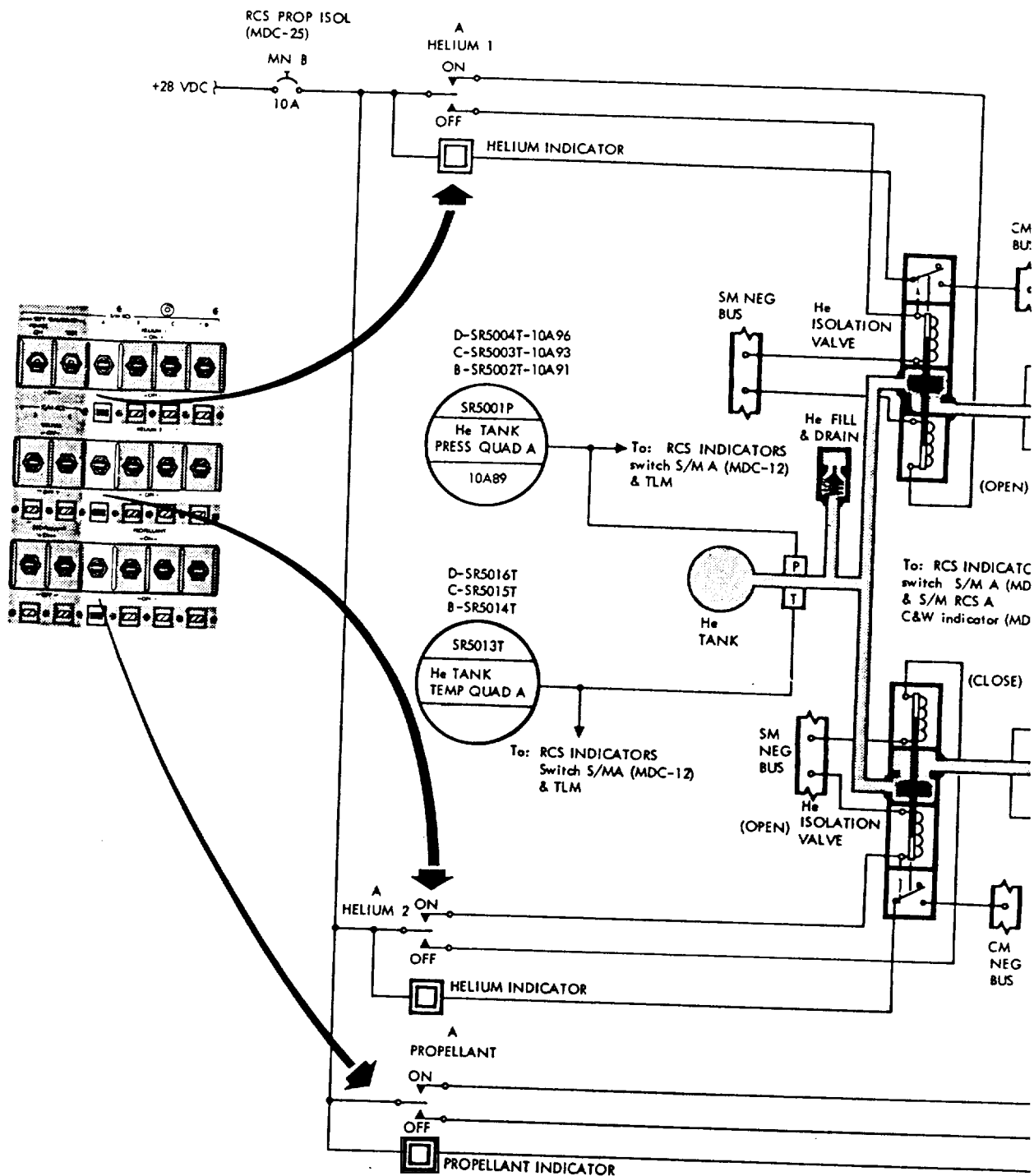
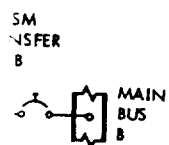




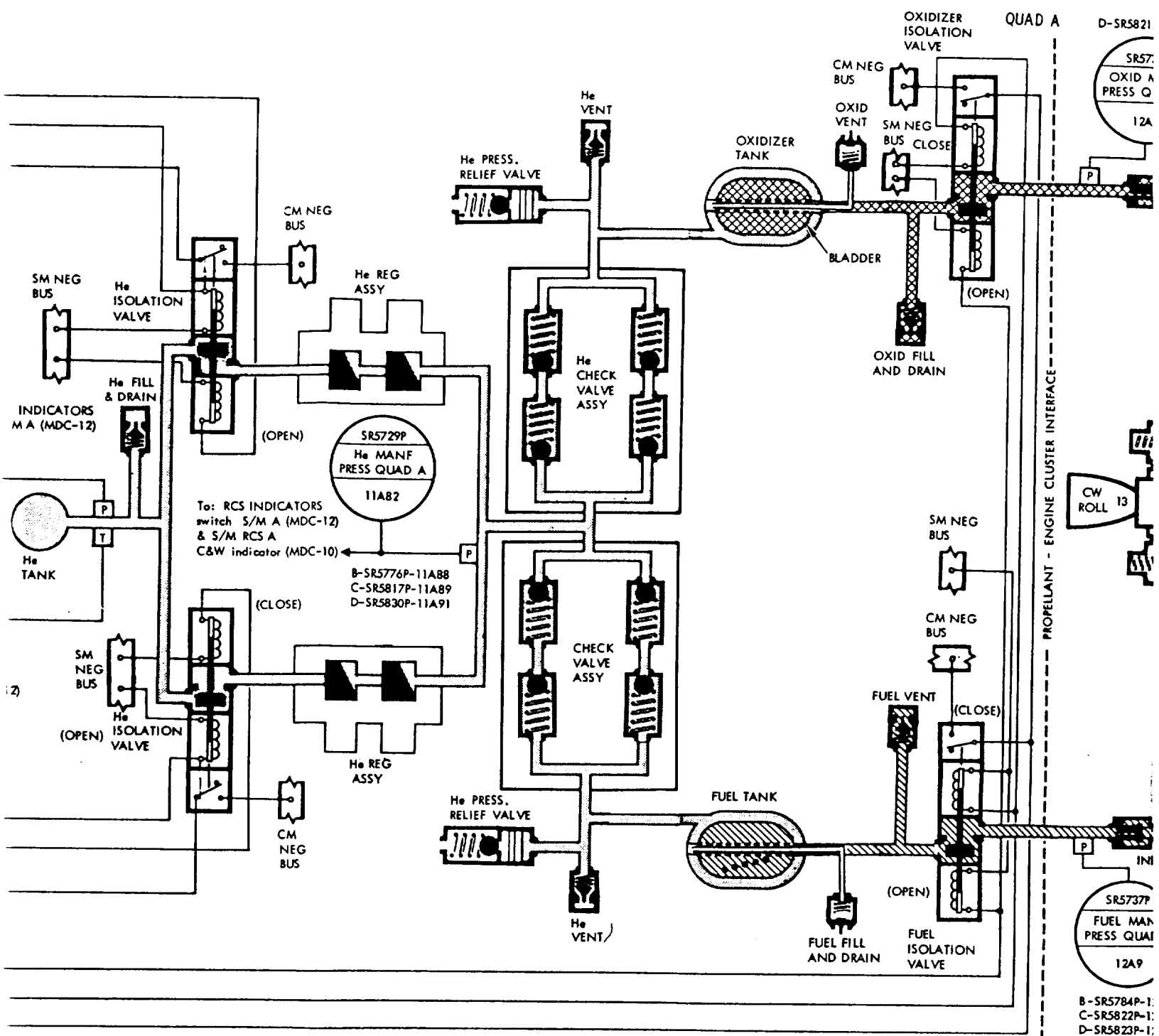
CONTROLS  
CONTROLS



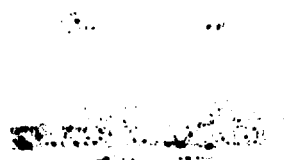
CM B CM SM  
LES ABORT

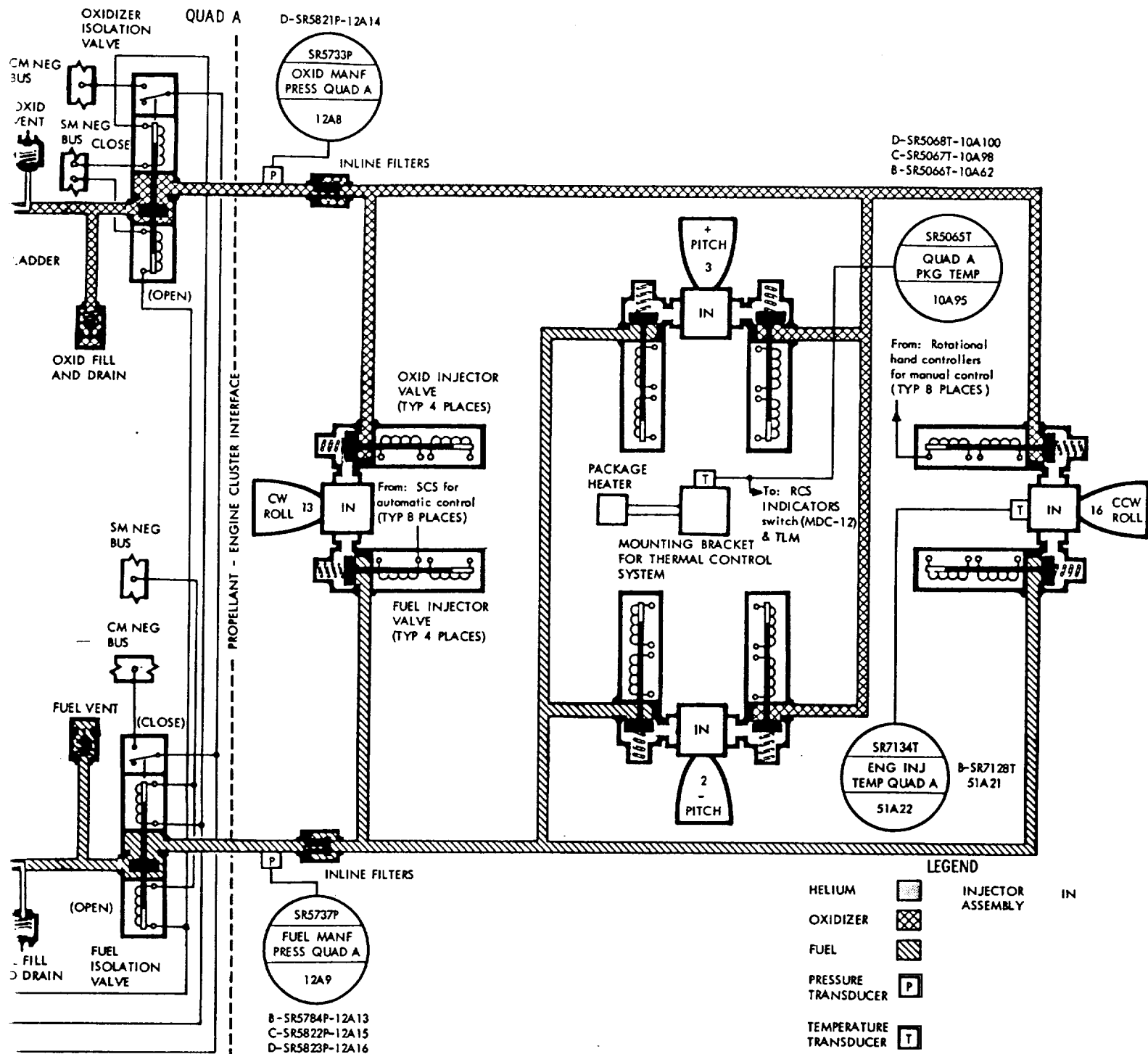






**BOLDOUT**





**KOLDOUT**

5

Mission





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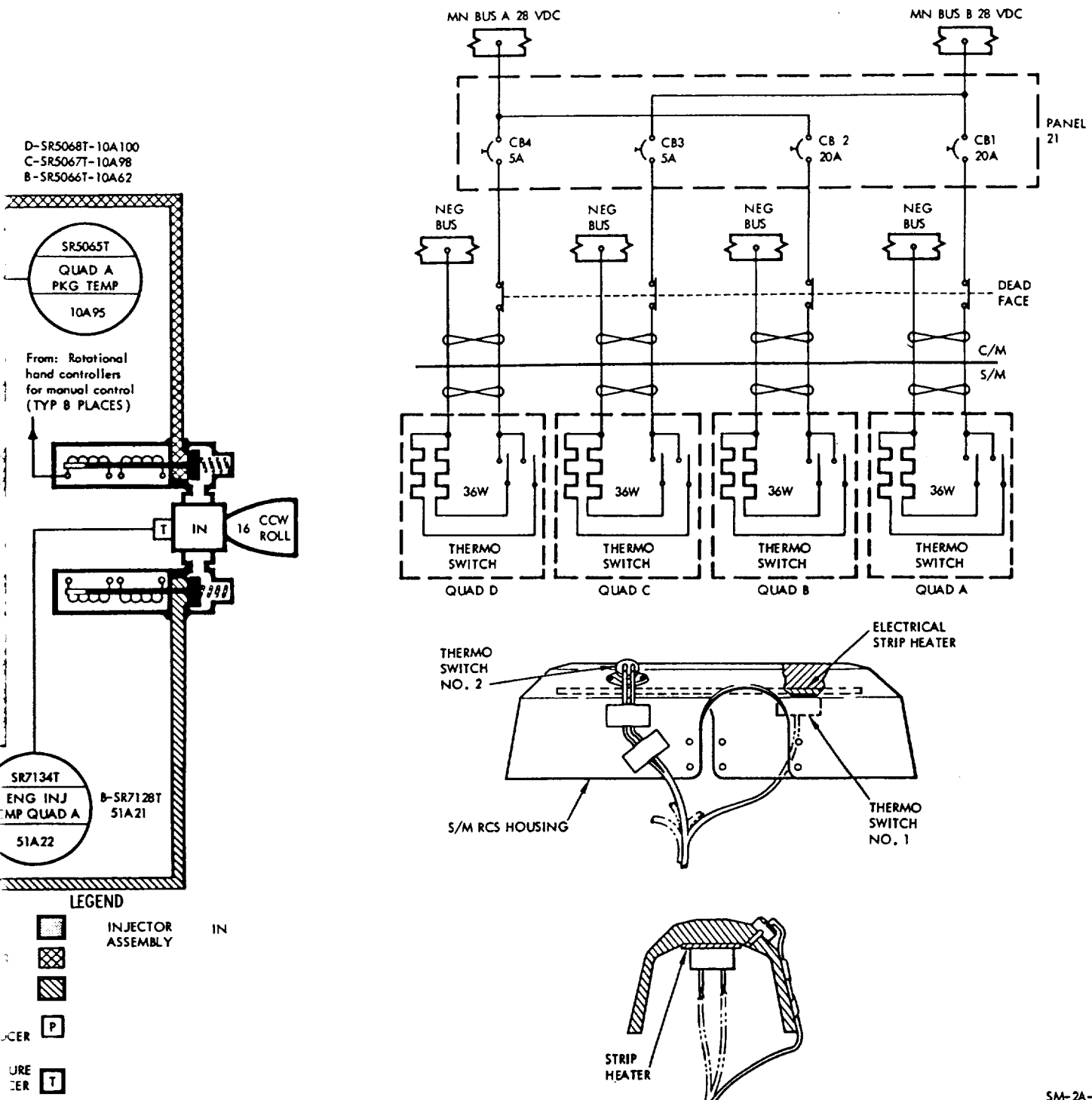


Figure 2.5-3. S/M RCS Functional Flow Diagram (Quad A)

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- Propellant quantity gauging
- Temperature control system

2.5.3.1 Pressurization Subsystem.

The pressurization and propellant feed stores, regulates, and distributes helium to the propellant tanks, and stores and distributes propellant to the engine assemblies (figure 2.5-3). It consists of storage tanks, isolation valves, pressure regulators, and the lines and valves necessary for filling, draining and distributing the fluids.

2.5.3.1.1 Helium Supply Tank.

The total high-pressure helium supply is contained within a single spherical storage tank. Initial fill pressure is  $4150 \pm 50$  psig at  $70^\circ\text{F}$ . The limit working pressure is 5000 psig to accommodate pressure transients during filling. Proof pressure is 6667 psig and the burst pressure is 7500 psig.

RCS

2.5.3.1.2 Helium Isolation Valve.

The helium isolation valves are a two-solenoid valves and are mechanically latched open and spring-loaded closed. The helium isolation valves are individually controlled by their own helium switch on panel 15. The valves are normally open in respect to system pressure substantiating the mechanical latching feature for power conservation purposes during the mission, in addition to preventing overheating of the valve coils.

A position switch contained within each valve controls a position indicator below each switch on panel 15. When the valve is open, the position switch is open; and the indicator on panel 15 is grey (same color as the panel) indicating the valve is in its normal position. When the valve is closed, the position switch is closed; and the indicator on panel 15 is diagonal lines indicating the valve is in its abnormal position. The valve is closed in the event of a pressure regulator unit problem and during ground servicing.

2.5.3.1.3 Pressure Regulator Assemblies.

Helium pressure regulation is accomplished by two regulator assemblies connected in parallel, with one assembly located downstream of each helium isolation valve. Each assembly incorporates two (primary and secondary) separate regulators connected in series. The secondary regulator remains open as long as the primary regulator functions properly. In the event of the primary regulator failing open, the secondary regulator will maintain slightly higher, but acceptable pressures.

2.5.3.1.4 Check Valve Assemblies.

Two check valve assemblies, one assembly located downstream of each regulator assembly, permit helium flow in the downstream direction

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only. This prevents propellant and/or propellant vapor backflow into the pressurization system if seepage or failure occurs in the propellant tank bladders.

2.5.3.1.5 Pressure Relief Valves.

The helium relief valve contains a burst diaphragm, filter, a bleed device, and the relief valve. The burst diaphragm is installed to provide a more positive seal against helium than that of the actual relief valve. The burst diaphragm ruptures at a predetermined pressure. The burst diaphragm is of the nonfragmentation type, but in the event of any fragmentation, the filter filters out any fragmentation and prevents any particles from flowing onto the relief valve seat. The relief valve will relieve at a pressure slightly higher than that of the burst diaphragm rupture pressure and relieve the excessive pressure overboard, protecting the fuel and oxidizer tank. The relief valve will reseal at a predetermined pressure.

A pressure bleed device is incorporated between the burst diaphragm and relief valve. The bleed valve vents the cavity between the burst diaphragm and relief valve in the event of any leakage from the diaphragm, or vents the cavity upon completion of performing a checkout of the relief valve from the test port on the relief valve. The bleed device is normally open and will close when the pressure increases up to a predetermined pressure. The bleed device automatically opens when the pressure decreases to the bleed valve opening pressure.

2.5.3.1.6 Distribution Plumbing.

Brazed joint tubing is used to distribute regulated helium in each RCS quad from the helium storage vessels to the propellant tanks.

2.5.3.2 Propellant Subsystem.

This subsystem consists of one oxidizer tank, one fuel tank, one oxidizer and fuel isolation valve, and associated distribution plumbing.

2.5.3.2.1 Oxidizer Tank.

The oxidizer supply is contained in a single titanium alloy hemispherically domed cylindrical tank. The tank is cradle-mounted to the RCS panel. The tank contains a diffuser tube assembly and a teflon bladder for positive expulsion of the oxidizer. The bladder is attached to the diffuser tube at each end of the tank. The diffuser tube acts as the propellant outlet.

When the tank is pressurized, the helium gas surrounds the entire bladder, exerting a force which causes the bladder to collapse about the propellant forcing the oxidizer into the diffuser tube assembly and out of the tank outlet into the manifold, providing expulsion during zero g's. Tank has a working pressure of 248 psig; proof pressure of 331 psig.

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2.5.3.2.2 Fuel Tank.

The fuel supply is contained in a single tank that is similar in material, construction, and operation to that of the oxidizer tank.

2.5.3.2.3 Propellant Isolation Shutoff Valve.

The isolation valves in the fuel and oxidizer lines are both controlled by a single switch on panel 15. The valves are two-solenoid valves and are magnetically latch opened and spring-loaded closed. The valves are normally open in respect to fluid flow. This, again, establishes a power conservation.

Each valve contains a position switch which is in parallel to one position indicator below the switch on panel 15 that controls both valves. When the position switch in each valve is open, the indicator on panel 15 is grey (same color as the panel) indicating to the crew that the valves are in the normal position. When the position switch in each valve or one valve is closed, the indicator on panel 15 is diagonal lines indicating to the crew that the valve or valves are closed. The valves are closed in the event of a failure downstream of the valves, line rupture, runaway thruster, etc.

RCS

2.5.3.2.4 Distribution Plumbing.

Propellant distribution plumbing within each quad is functionally identical. Each quad contains separate similar oxidizer and fuel plumbing networks. Propellants within their respective networks are directed from the supply tanks, through manifolds for distribution to the four engines in the cluster.

2.5.3.2.5 Propellant, In-Line Filters.

In-line filters are installed in the fuel and oxidizer manifolds downstream of the propellant shutoff valves and prior to the engine manifold contained within the engine housing. The in-line filters are installed to prevent any particles from flowing into the engine injector valves and engine injector.

2.5.3.3 Engine Assemblies.

The service module reaction control system engines are radiation-cooled, pressure-fed, bipropellant thrust generators which can be operated in either the pulse modulated or the steady state mode. (These modes are defined as a firing of less than one-second duration, and one-second duration or more, respectively.)

Each engine consists of a fuel and oxidizer control valve, which controls the flow of propellants by responding to electrical commands (automatic or manual) generated by the guidance and navigation subsystem and/or stabilization and control subsystem or by the crew; and an injector

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head assembly, which directs the flow of each propellant from the propellant control valves to the combustion chamber where the propellants atomize and ignite (hypergolic) to produce thrust.

2.5.3.3.1 Propellant Solenoid Injector Control Valves (Fuel and Oxidizer).

The propellant solenoid injector valves utilize two coaxially wound coils: one for automatic and one for direct manual operation. The automatic coil is used when the thrust command originates from the jet selection logic, which is the electronic circuitry that selects the required automatic coils to be energized for a given maneuver. The manual coils are used when the thrust command originates at the rotation control (direct mode), direct ullage pushbutton, SPS abort, or the C/M S/M SEP switch (figure 2.5-3).

The solenoid valves are spring-loaded closed and energized open. The reaction time of the valves are illustrated in figures 2.5-4 and 2.5-5.

Figure 2.5-4 illustrates a thrusting duration of 15 seconds (steady state). The electrical on signal is received within either the automatic (normal) or manual (backup) coils of the engine injector valves. The solenoid injector valves are energized open allowing fuel and oxidizer to

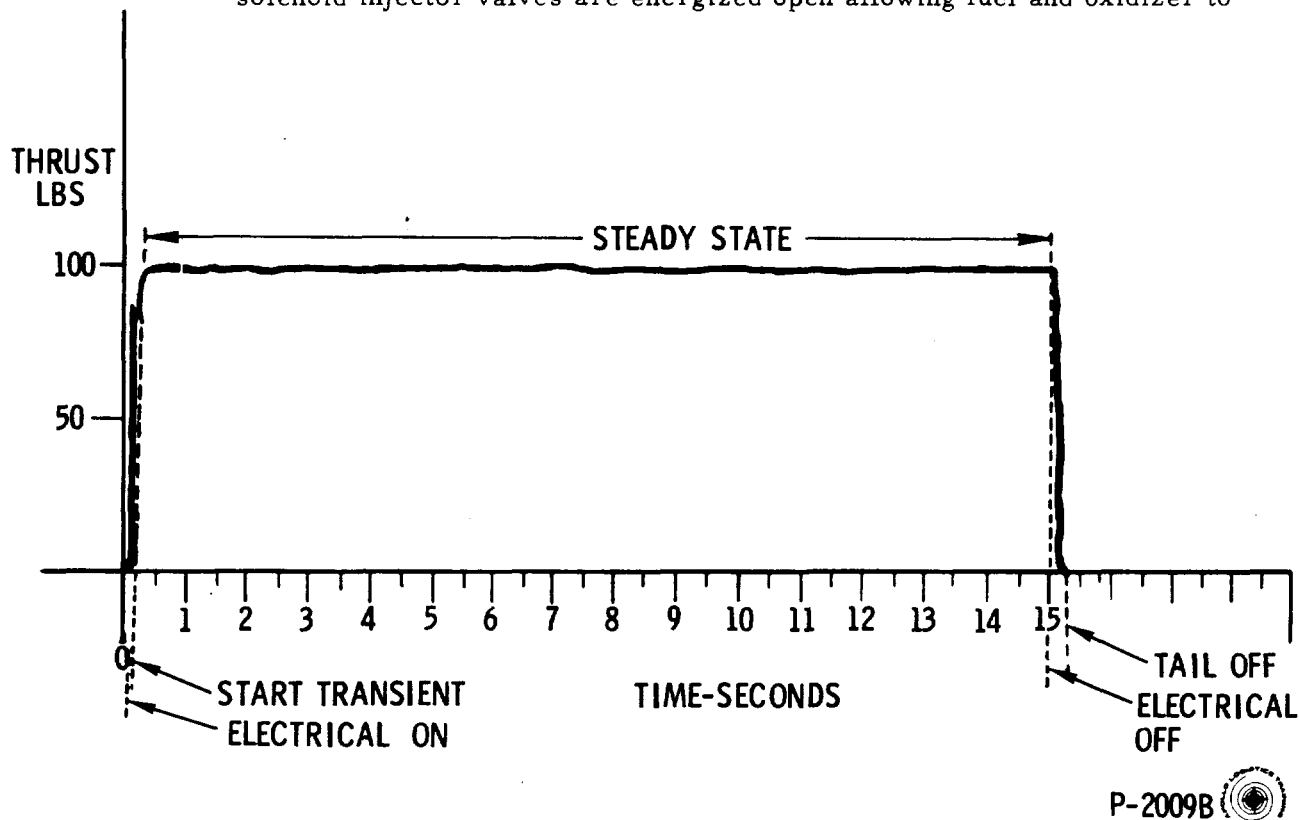


Figure 2.5-4. S/M RCS Steady-State Operation (Typical 15 Seconds)

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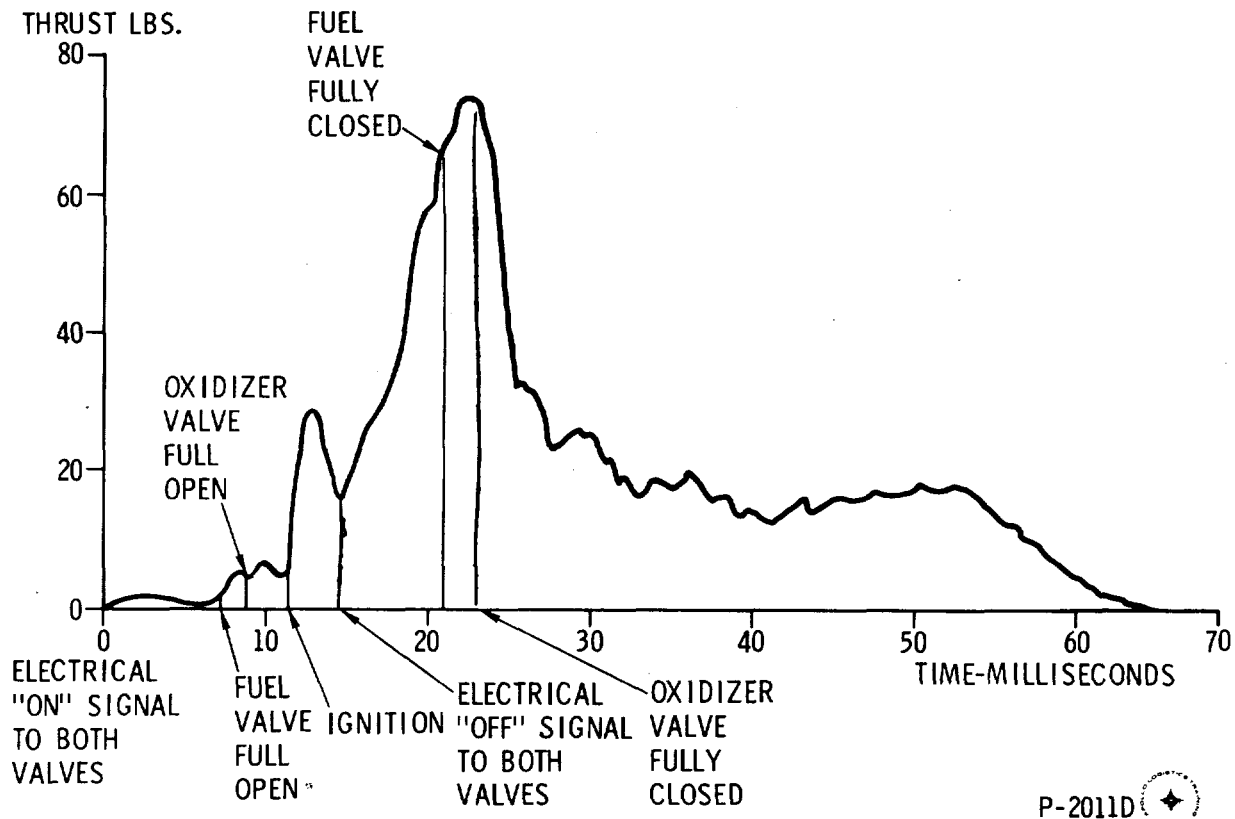


Figure 2.5-5. S/M RCS Engine Minimum Total Impulse (Typical)

flow through the injector into the combustion chamber. The propellants, being hypergolic, ignite, providing the start transient. The engine, as a result of propellant ignition, produces chamber pressure, gas velocity, and thrust. At 15 seconds after the receipt of the thrust-on signal, the automatic or manual coils are de-energized and the injector valves spring-load closed. However, due to the closing time and residual propellant flow downstream of the injector valves into the combustion chamber, thrust output continues until the propellants have burned completely allowing the chamber pressure, gas velocity, and thrust to decay to 0 pounds, establishing the cutoff transient.

Figure 2.5-5 illustrates the minimum electrical signal that can be provided to the automatic coils of the injector valves from the stabilization control subsystem jet selection logic. The following describes the sequence of operation and reasons why.

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- a. A time of  $18 \pm 4$  milliseconds (14 milliseconds minimum) will elapse before the stabilization control subsystem (SCS) can electrically provide a command-off signal to the automatic coils of the injector valves on the engine.
- b. When the automatic coils of the injector valves receive the electrical on signal from the SCS, the injector valves are energized to the open position.
- c. The fuel injector automatic coil energizes to the fully open position in  $4.5 \pm 1.5$  milliseconds, and the oxidizer injector automatic coil energizes to the fully open position in  $6.0 \pm 1.5$  milliseconds establishing an approximate 2 millisecond fuel lead. This is accomplished by varying the resistance of the automatic coils in the fuel and oxidizer injector valve.
- d. The propellants flow from the injector valves as soon as they both start to open to the premix igniter. However, the fuel will lead the oxidizer by two milliseconds.
- e. The propellants start to flow, as soon as the injector valves start to open, into the premix igniter and into the combustion chamber which creates some pressure, gas velocity and thrust, and even though it is very small, the engine is operating in a space environment.
- f. The pressure, gas velocity, and thrust continues to increase slightly until the valves reach the fully open position.
- g. At approximately 12-1/2 milliseconds, the propellants ignite (hypergolic), producing a spike of thrust upwards into the area of 70 to 80 pounds. At 14 milliseconds minimum, the SCS removes the electrical signal from the automatic coils of the injector valves.
- h. The thrust of the engine continues very erratically, while the valves become de-energized and spring-load closed.
- i. At approximately 21 milliseconds (closing time of 7.5 milliseconds) on the fuel valve and 23 milliseconds (closing time of 8.0 milliseconds) on the oxidizer valve, the injector valves are fully closed.
- j. The residual propellants downstream of the injector valves continue to flow into the combustion chamber, decreasing until complete thrust decay of 0 pounds occurs at approximately 65 milliseconds.
- k. In order to determine the total impulse for this time span of operation (figure 2.5-5), everything under the entire thrust curve must be integrated.

The automatic coils are electrically connected in parallel from the SCS. The manual coils in the fuel and oxidizer injector valves provide a manual direct backup to the SCS mode of operation. The manual coils of the injector valves are electrically connected in series. The reasons for the series connection of the manual coils are as follows:

- a. Prevent a mismatch between the opening and closing of the valves due to any heat soak-back into the manual coils, which would change the resistance of the manual coils and result in a mismatch if the coils were connected in parallel. The direct manual opening time for fuel is 13 milliseconds and oxidizer is 23 milliseconds. The closing time for fuel and oxidizer is  $55 \pm 25$  milliseconds.

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b. The series connection from the fuel manual coil (positive to negative) to the oxidizer manual coil (negative to positive), then to ground, is to increase the arc suppression, reducing the arc at rotation control in the direct RCS mode of operation.

2.5.3.3.2 Injector.

The injector contains a premix igniter. The premix igniter chamber contains a fuel and an oxidizer passage that impinge upon each other (unlike impingement) within the premix igniter chamber. The premix igniter chamber, along with the 2-millisecond fuel lead, provides a smoother start transient primarily in the pulse mode of operation and especially in the area of minimum impulse.

The main chamber portion of the injector will allow eight fuel streams to impinge upon eight oxidizer streams (unlike impingement) for main chamber ignition. There are also eight fuel holes around the outer periphery of the injector, which provides film cooling to the combustion chamber.

RCS

2.5.3.3.3 Combustion Chamber.

The combustion chamber is constructed of unalloyed molybdenum, which is coated with a thin layer of molybdenum disilicide to prevent oxidation of the base metal. Cooling of the chamber is by radiation and film cooling.

Nozzle Extension. The nozzle extension is attached to the engine by a Waspolloy nut. The nozzle extension is machined from a cobalt base alloy. The stiffener rings are machined.

2.5.3.3.4 RCS Electrical Heaters.

Each of the RCS engine housings contain an electrical strip heater (figure 2.5-3). The electrical strip heaters provide propellant temperature control by conductance to the engine housing and engine injector valves; thus the propellants. Each heater has two thermo switches that maintain the temperature at a given range.

2.5.3.4 Pressure Versus Temperature Measuring System.

The helium tank supply temperature measurement and helium tank supply pressure measurement (figure 2.5-3) for each quad are utilized by the crew and TLM to determine the quantity of propellants remaining in the respective quad.

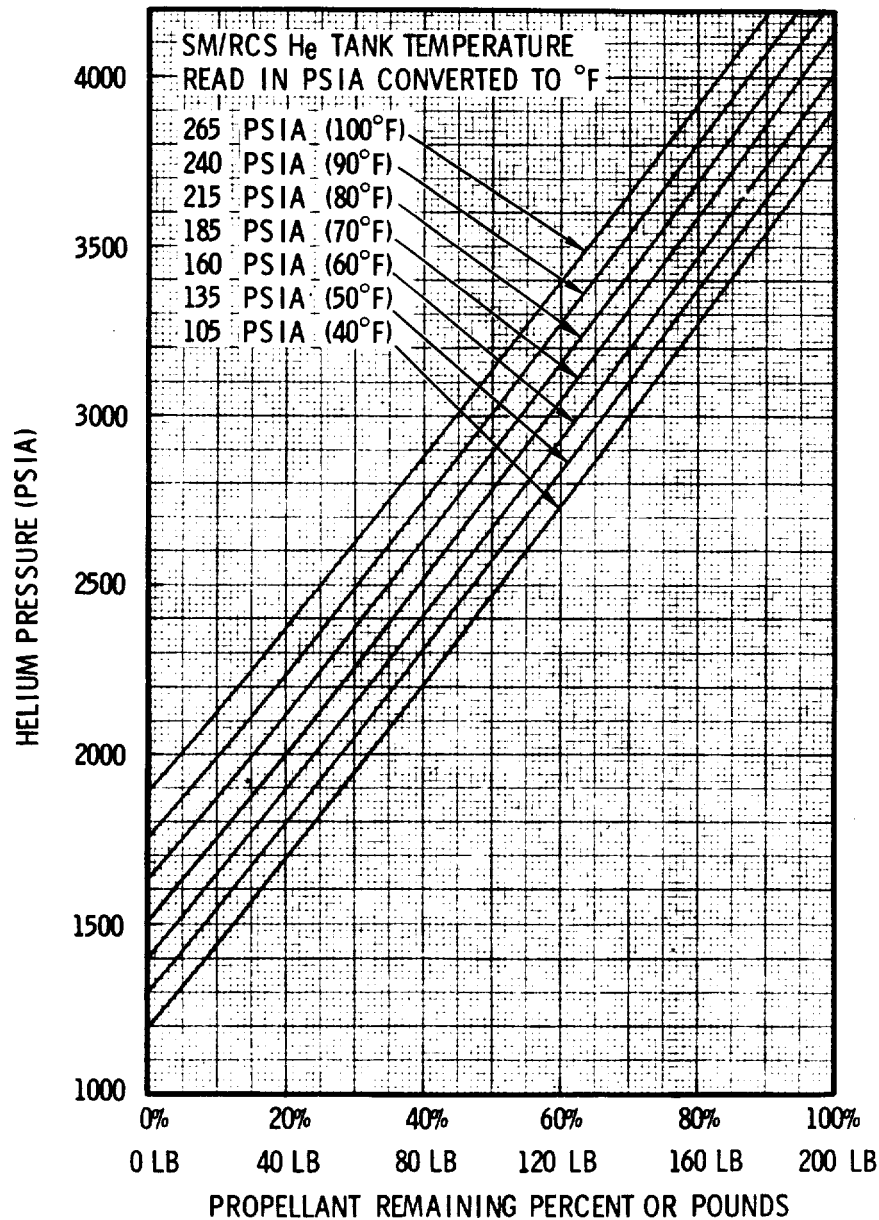
The nomogram (figure 2.5-6) depicts how to determine the propellant quantity remaining in percentage. The helium supply pressure is determined in psia on panel 12 by the crew, also the helium supply temperature

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Figure 2.5-6. S/M RCS Nomogram Typical Propellant Remaining

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reads in psia. The helium supply temperature readout of 0 psia is equivalent to 0°F and 400 psia is equivalent to 150°F.

As an example, if the crew readout on panel 12 for a given quad reads 3400 psia helium supply pressure and 265 psia helium supply temperature (which is equivalent to 100°F), the quantity of propellants remaining is approximately 60 percent or 120 pounds. The crew would utilize the RCS indicator select switch on panel 12 to select the quad desired in order to obtain the helium tank supply pressure and temperature, and determine the propellant quantity remaining in percent.

2.5.3.5

Engine Thrusting Logic.

In the S/M RCS, the commands from the stabilization and control system cannot be supplied to the SCS channel switches until the contacts of the RCS latching relay are closed. Closing of these contacts for S/M RCS control may be initiated by the following signals (figure 2.5-3):

a. With the launch escape tower jettisoned and the translation control rotated counterclockwise, an S/M abort or a normal S-IVB separation is initiated and the following sequence of events occurs.

1. Inform the G&N system of an abort initiation.
2. Initiate applicable booster shutdown.
3. Inhibit the pitch and yaw automatic jets of the SCS.
4. Initiates an ullage maneuver signal to the required manual coils of the S/M RCS engines (as long as the translation control is in counterclockwise, ullage is terminated when the translation control is returned to the neutral detent).
5. Adapter separation occurs at 1.7 seconds after the abort was initiated.
6. Energizes the RCS latching relay 2-1/2 seconds after the abort was initiated allowing the SCS to provide electrical commands to the automatic coils of the S/M RCS engines. In the event the logic fails to energize the RCS latching relay, the RCS CMD switch on panel 16 is placed to the ON position, providing a manual backup to the automatic function. In addition, if the ADAPTER SEPARATION pushbutton on panel 5 is pressed and held for approximately 1 to 2 seconds, the RCS latching relay is energized.

b. In a backup to the normal S-IVB separation sequence, the RCS CMD switch is momentarily placed to the ON position, energizing the RCS latching relay; the translation control is positioned forward, providing a translation through the SCS to the required automatic coils of the S/M RCS engine for a +X translation; and the ADAPTER SEPARATION pushbutton on panel 5 is held for 2 seconds to initiate adapter separation. (ADAPTER SEPARATION pushbutton pressed and held for approximately 1 to 2 seconds will also energize the RCS latching relay.)

In the event the translation controls are unable to provide an ullage maneuver, the DIRECT ULLAGE pushbutton on panel 7, when depressed

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and held, provides the direct ullage signal to the manual coils of the RCS engines, to be energized to provide a +X translation. This provides a manual direct backup to the two translation controls for the ullage maneuver to be performed by the S/M RCS. The ullage maneuver is terminated upon release of the DIRECT ULLAGE pushbutton.

In the event the SCS and/or jet selection logic is unable to provide commands to the automatic coils of the S/M RCS engines, placing the DIRECT RCS switch on panel 8 to the ON position provides power to the rotation controls only. When the rotation control is positioned fully to its stops in any direction, the rotation control will energize the required manual coils for the desired maneuver.

If the SCS and/or the jet selection logic is unable to provide commands to the automatic coils of the S/M RCS engines, it is noted that translation control of the spacecraft is disabled.

2.5.4 S/M RCS PERFORMANCE AND DESIGN DATA.

2.5.4.1 Design Data.

The following list is the design data of the S/M RCS components.

HELIUM TANKS (4)	4150±50 psig at 70±5°F during servicing; after servicing sitting on launch pad 70±10°F. Capacity 0.57 lb, inside diameter 8.84 in., wall thickness 0.105 in., and internal volume 0.205 cu ft.
REGULATOR UNITS (8)	Primary - 181±4 psig with a normal lockup of 183±5 psig. From lockup pressure, not drop below 177 psig or rise above 185 psig and stabilize to 181±2 psig within 2 sec.  Secondary - Lockup of 187±5 psig. From lockup pressure, not drop below 177 psig or rise above 194 psig and stabilize at 185±3 psig within 2 sec.
PRESSURE TRANSDUCERS (4) COMMON MANIFOLD	Illuminate CAUTION and WARNING light on panel 10 (S/M RCS A, B, C, or D). Underpressure 155 psia. Overpressure 215 psia.
HELIUM RELIEF VALVES (8)	Diaphragm rupture at 228±8 psig.  Filter - 10 micron nominal, 25 micron absolute.

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	Relief valve relieves at $236.5 \pm 11.5$ psig.	
	Relief valve reseats at not less than 220 psig in the cavity and a helium flow of less than 20 standard cubic centimeters per hour across the bleed device and relief valve assembly combined. The bleed device shall reopen when decreasing pressure has reached no less than 20 psig.	
FUEL TANK (4)	Combined propellant and ullage volume of 69.0 lbs, initially at $60^{\circ}\text{F}$ at $30 \pm 2$ psig, resulting in a tank pressure of no more than 215 psia when heated to $85^{\circ}\text{F}$ . Outside diameter maximum 12.62 in., length 23.717 (+0.060, -0.000) in. Wall thickness 0.017 in. to 0.022 in.	RCS
	Helium inlet port 1/4 in., fill and drain port 1/2 in.	
OXIDIZER TANK (4)	Combined propellant and ullage volume of 137.0 lbs, initially at $65^{\circ}\text{F}$ at $30 \pm 2$ psig, resulting in a tank pressure of no more than 215 psia when heated to $85^{\circ}\text{F}$ . Outside diameter maximum 12.62 in., length 28.55 (+0.060, -0.000) in.	
	Wall thickness 0.017 in. to 0.022 in.	
INLINE FILTERS ENGINES (16)	5-micron nominal; 15-micron absolute - 1000-sec service life, capable of 10,000 operational cycles.	
	Thrust 100 lbs $\pm 5$ percent.	
	Expansion ratio 40:1 at nozzle exit.	
	Cooling      Film and radiation	
	Injector type.	
	Premix igniter one on one unlike impingement. Eight fuel annulus for film cooling of premix igniter, main chamber eight on eight unlike impingement, eight fuel for film cooling of combustion chamber wall.	

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	Nozzle extension	L-605 material
	Nozzle exit diameter	5.6 in.
	Fuel lead.	
	Automatic coils -	Connected in parallel.
	Manual coils -	Connected in series.
	Weight -	4.99 lbs.
	Length -	13.375 in.
PACKAGE TEMPERATURE TRANSDUCER (4)	Illuminate CAUTION and WARNING light on panel 10 (S/M RCS A, B, C, or D)	
	Under temperature 63°F.	
	Over temperature 175°F.	
	<u>One in Each Quad</u>	<u>One in Each Quad</u>
HEATERS THERMO-SWITCH	Close at 77 (+10, -7)°F	Close at 115°F
	Open at 104±14°F	Open at 134°F
	36±3.6 watts per heater	36±3.6 watts per heater

2.5.4.2 Performance Data.

Refer to Mission Modular Data Book, SID 66-1177.

2.5.4.3 Power Consumption Data S/M RCS and C/M RCS.

Subsystem and Component	Control	No. of Units	Watts per Unit		Total Watts	
			AC	DC	AC	DC
Reaction control Service module RCS						
Engine heaters	RCS HEATER CB (4)	8		*36.0		288.0
RCS engine coils	SCS JET SELECTION LOGIC or DIRECT	32		*AUTO = 3.687		118.0
				*DIRECT = 1.062		34.0

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Subsystem and Component	Control	No. of Units	Watts per Unit		Total Watts	
			AC	DC	AC	DC
He isolation valves	He VALVE CB (2) He sw (8)	8		6.750		54.0
Propellant isolation valves	PROP. ISOL. CB (2) PROP. ISOL. sw (4)	8		6.125		49.0
Command module RCS						
Isolation valves	(Ref. S/M/RCS ISOL. CB) PROP. ISOL. sw (2)	4		12.250		49.0
RCS engine coils	SCS JET SELECTION LOGIC OR DIRECT	24		*AUTO = 4.208  *DIRECT = 2.187		105.0  52.5

RCS

\*Intermittent operating components.

2.5.4.4 S/M RCS Electrical Power Distribution.

See figure 2.5-7 for electrical power distribution.

2.5.5 S/M RCS OPERATIONAL LIMITATIONS AND RESTRICTIONS.

Operational limitations and restrictions on the testing of system valves in a dry unserviced propulsion system are as follows:

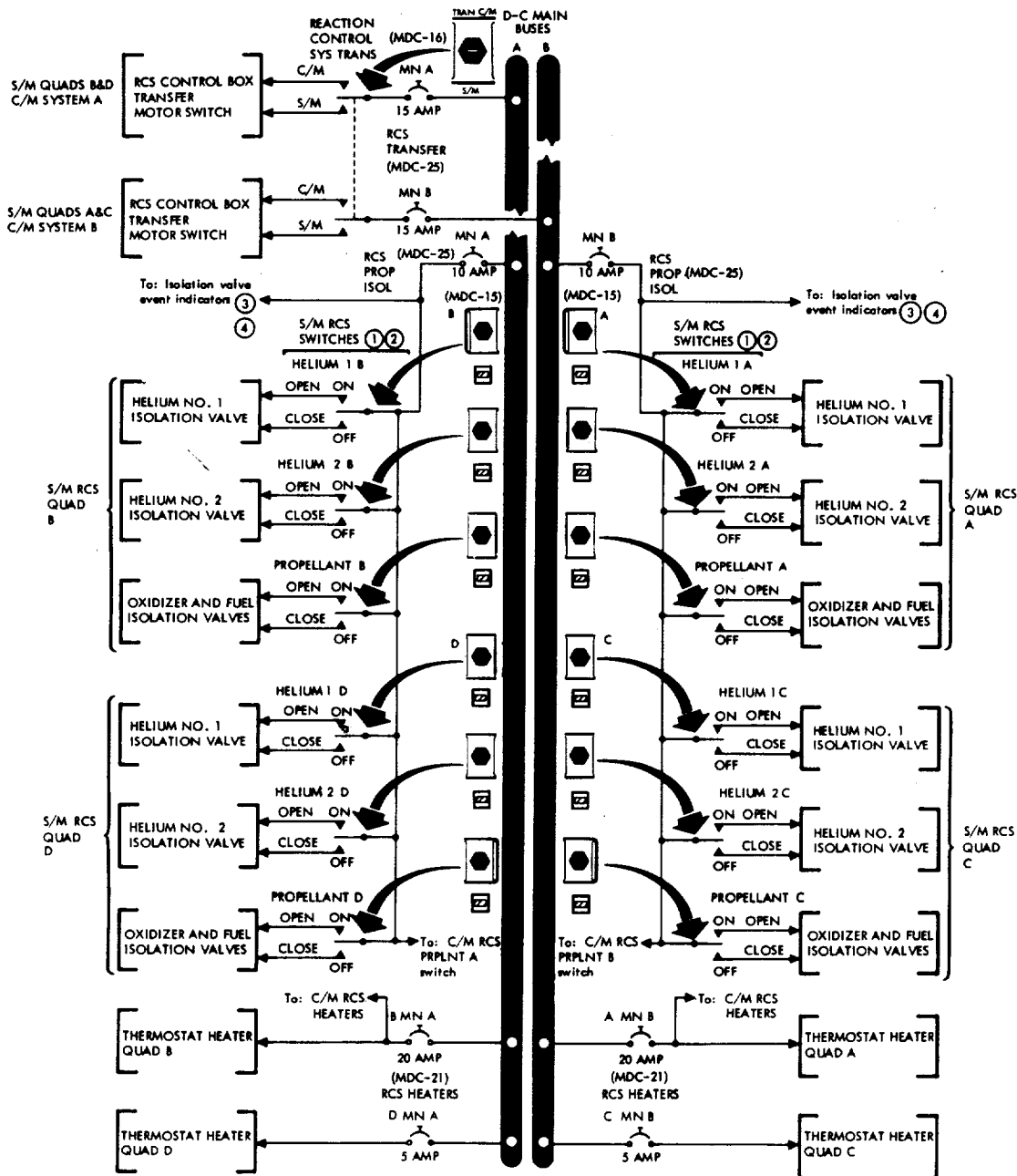
- a. Helium isolation valves and propellant isolation valves minimum energization time of 0.2 second and not to exceed 5 seconds.
- b. Engine injector valve automatic coil energization not to exceed 2 minutes on time during any 15-minute period with voltage not exceeding 32 vdc.
- c. Engine injector valve direct coil energization on time not exceed 45 minutes during any 60-minute period and voltage not exceed 16 vdc to either coil separately or 32 vdc to two coils in series.

2.5.6 S/M RCS TELEMETRY MEASUREMENTS.

The subsequent list is of all S/M RCS telemetry data that is monitored by flight controllers and ground support personnel.

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- NOTES: 1. Helium isolation valves are mechanically latched open and spring-loaded closed.  
 2. Propellant isolation valves are magnetically latched open and spring-loaded closed.  
 3. Each helium isolation valve event indicator is energized when corresponding valve is in closed position only.  
 4. The propellant isolation valve event indicator is energized if either fuel or oxidizer valve is in the closed position.

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Figure 2.5-7. S/M RCS Electrical Power Distribution Diagram

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Crew Display	Figure	Measurements	Measure- ment Number	Range	Signal Conditioner	Channel Code*	Bit Rate*	*	Operating Range
Panel 12	2.5-3	Helium Tank Temperature A	SR5013T	0 +150° F	S28AR164(S19A1)			{	70±10° F on launch pad, variable during mission.
Panel 12	2.5-3	Helium Tank Temperature B	SR5014T	0 +150° F	S28AR164(S19A2)				
Panel 12	2.5-3	Helium Tank Temperature C	SR5015T	0 +150° F	S28AR164(S19A3)				
Panel 12	2.5-3	Helium Tank Temperature D	SR5016T	0 +150° F	S28AR164(S19A4)				
Panel 12	2.5-3	Helium Tank Supply Pressure A	SR5001P	+0 +5K psia	S28AR36(S19A1)	10A89	H2	{	4150±5° F psia and decreases with engine firings.
Panel 12	2.5-3	Helium Tank Supply Pressure B	SR5002P	+0 +5K psia	S28AR36(S19A2)	10A91	H2		
Panel 12	2.5-3	Helium Tank Supply Pressure C	SR5003P	+0 +5K psia	S28AR36(S19A3)	10A93	H2		
Panel 12	2.5-3	Helium Tank Supply Pressure D	SR5004P	+0 +5K psia	S28AR36(S19A4)	10A96	H2		
Panel 10 and 12	2.5-3	Regulated Helium Manifold Pressure A	SR5729P	+0 +400 psia	S28AR44(S19A1)	11A82	H2	{	Launch pad 193 to 207 psia decreasing to 178 to 192 psia in a space environment.
Panel 10 and 12	2.5-3	Regulated Helium Manifold Pressure B	SR5776P	+0 +400 psia	S28AR44(S19A2)	11A88	H2		
Panel 10 and 12	2.5-3	Regulated Helium Manifold Pressure C	SR5817P	+0 +400 psia	S28AR44(S19A3)	11A89	H2		
Panel 10 and 12	2.5-3	Regulated Helium Manifold Pressure D	SR5830P	+0 +400 psia	S28AR44(S19A4)	11A91	H2		
	2.5-3	Oxidizer Feed Line Pressure A	SR5733P	+0 +300 psia		12A8	H1	{	Launch pad 193 to 207 psia decreasing to 178 to 192 psia in a space environment.
	2.5-3	Fuel Feed Line Pressure A	SR5737P	+0 +300 psia		12A9	H1		
	2.5-3	Fuel Feed Line Pressure B	SR5784P	+0 +300 psia		12A13	H1		
	2.5-3	Oxidizer Manifold Pressure D	SR5821P	+0 +300 psia		12A14	H1		
	2.5-3	Fuel Feed Line Pressure C	SR5822P	+0 +300 psia		12A15	H1	{	Pad 115 to 134° F Flight 115° F to 175° F
	2.5-3	Fuel Feed Line Pressure D	SR5823P	+0 +300 psia		12A16	H1		
Panel 10 and 12	2.5-3	Temperature Package A + P Engine 3	SR5065T	+0 +300° F	S28AR40(S19A1)	10A95	H1		
Panel 10 and 12	2.5-3	Temperature Package B - Y Engine 6	SR5066T	+0 +300° F	S28AR40(S19A2)	10A62	H1		

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Helium entering the propellant tanks creates a pressure buildup around the propellant positive expulsion bladders, forcing the propellants to be expelled into the propellant distribution lines. Propellants then flow to valve isolation burst diaphragms, which rupture, and through the propellant isolation valves. Each subsystem supplies fuel and oxidizer to six engines.

Oxidizer and fuel is distributed to the 12 fuel and oxidizer injector valves by a parallel feed system. The fuel and oxidizer injector valves on each engine contain orifices which meter the propellant flow to obtain a nominal 2:1 oxidizer/fuel ratio by weight. The oxidizer and fuel impinge, atomize, and ignite due to the hypergolic propellants. The injector valves are controlled automatically by the G&N system or the SCS. Manual override direct control is provided for rotational maneuvers and direct ullage only. The injector valves are spring-loaded closed.

Extremely cold temperature of the C/M exterior is anticipated prior to entry operations; therefore, C/M RCS engine preheating may be necessary before initiating pressurization due to possible freezing of the oxidizer (+11.8°F) upon contact with the engine injector valves. This is accomplished by the crew monitoring the engine temperatures and energizing the injector valve solenoids until acceptable engine temperatures are obtained. The C/M RCS HTRS switch on panel 200 will apply power to the injector valve solenoids for engine preheating.

Since the presence of hypergolic propellants can be hazardous upon C/M impact, the remaining propellants are burned off and the RCS purged with helium prior to C/M landing.

In the event of an abort from the pad up to T + 61 seconds after liftoff, provisions have been incorporated to automatically dump the oxidizer supply overboard, followed by a helium purge of the oxidizer tanks and dumping of the remaining helium supply. The fuel is retained on board due to insufficient time for dumping and the C/M impacts with fuel tanks full, but depressurized.

2.5.8

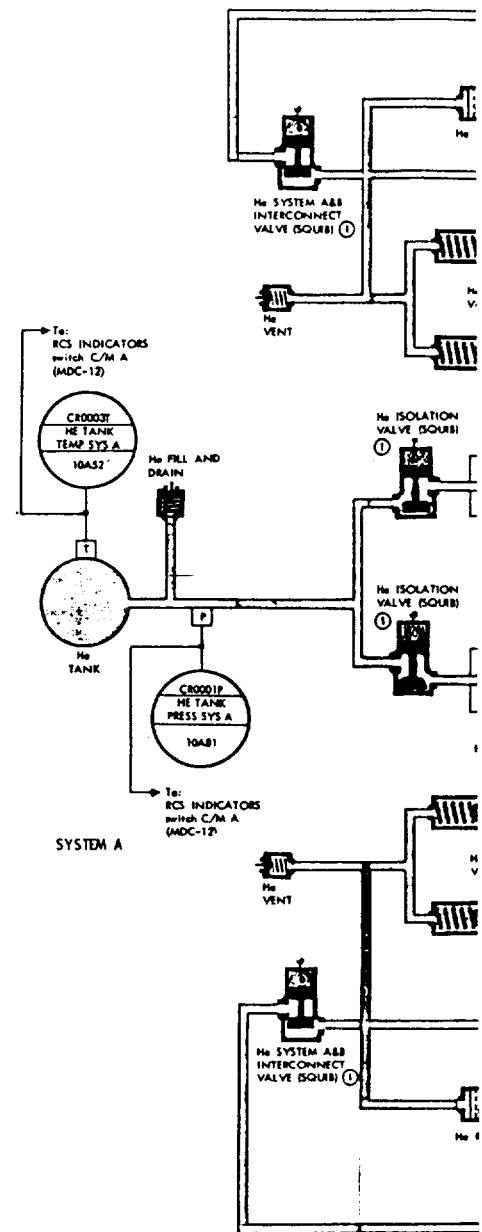
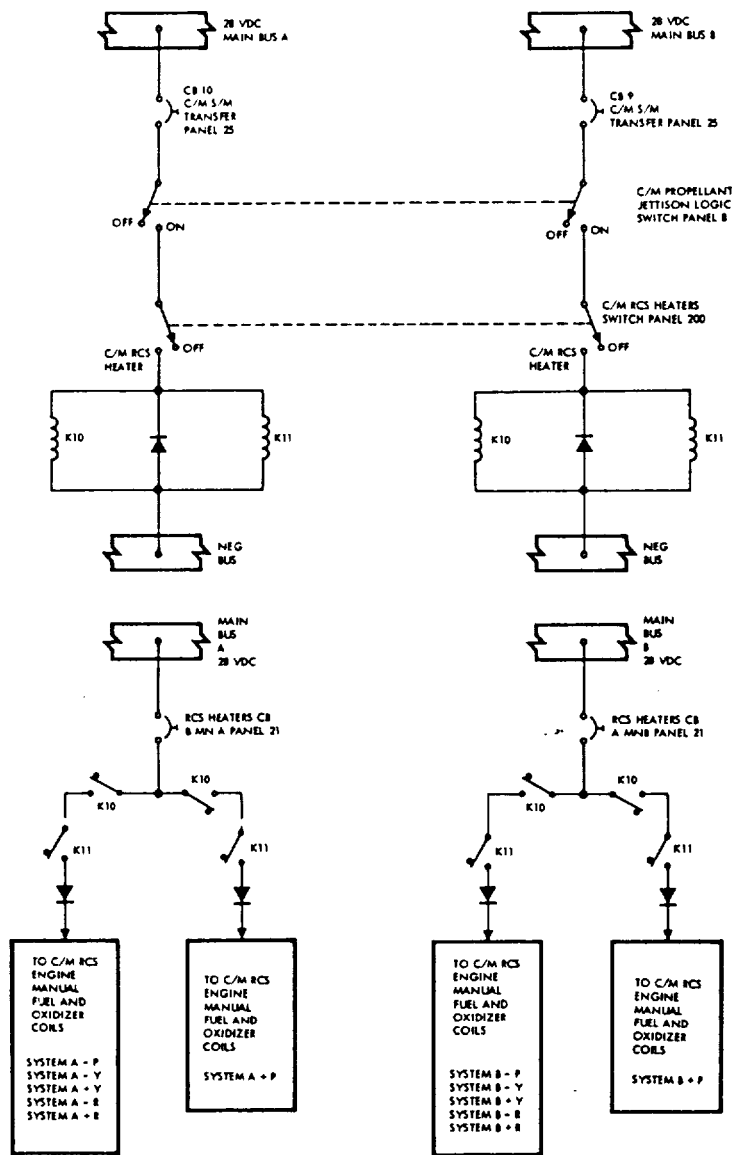
C/M RCS MAJOR COMPONENTS/SUBSYSTEM DESCRIPTION.

The C/M RCS is composed of two separate, normally independent systems, designated system A and system B. The systems are identical to operation, each containing the following four major subsystems:

- Pressurization
- Propellant
- Rocket engine
- Temperature control system

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REACTION CONTROL SYSTEM

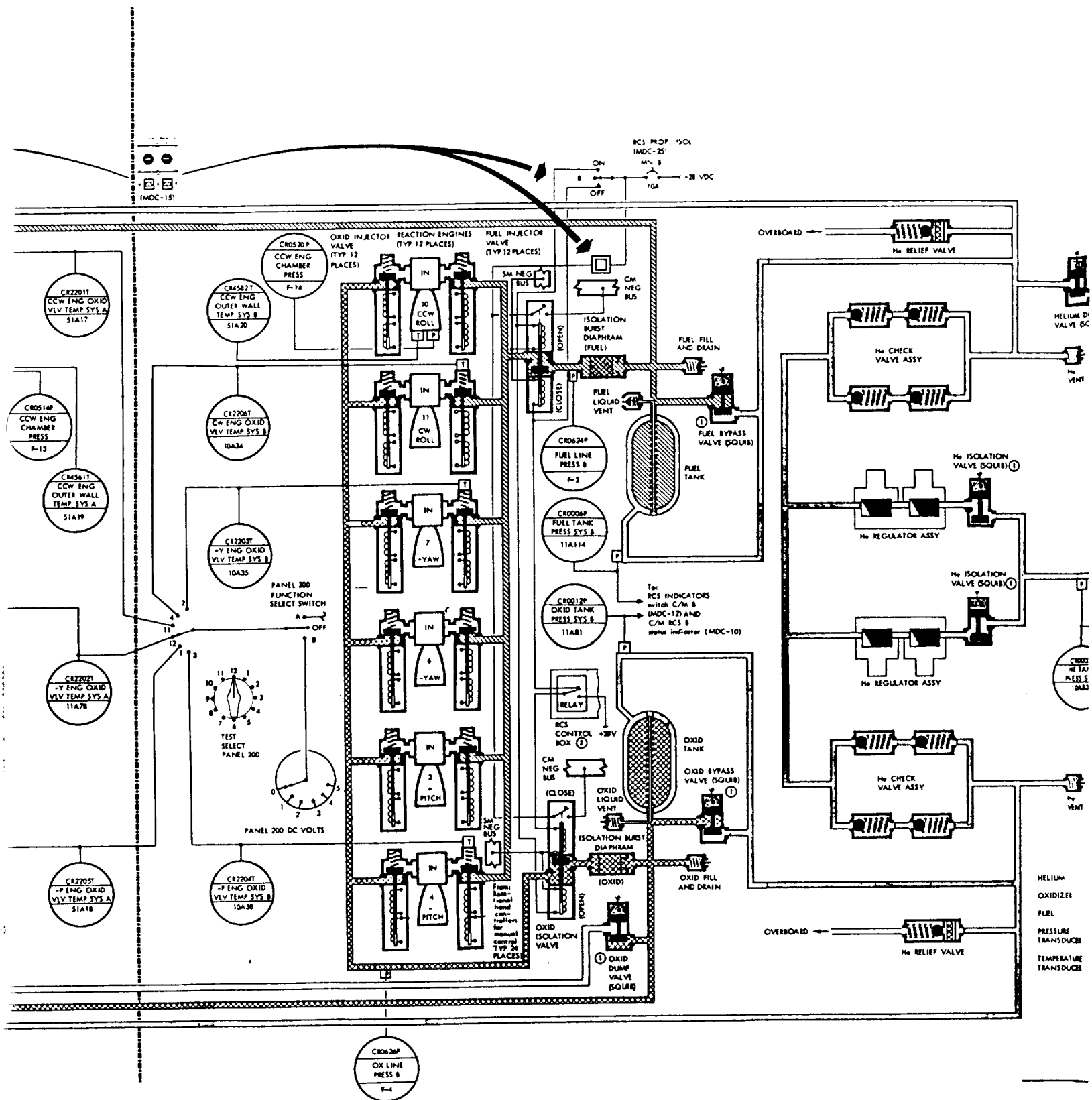


FOLDOUT FRAME /













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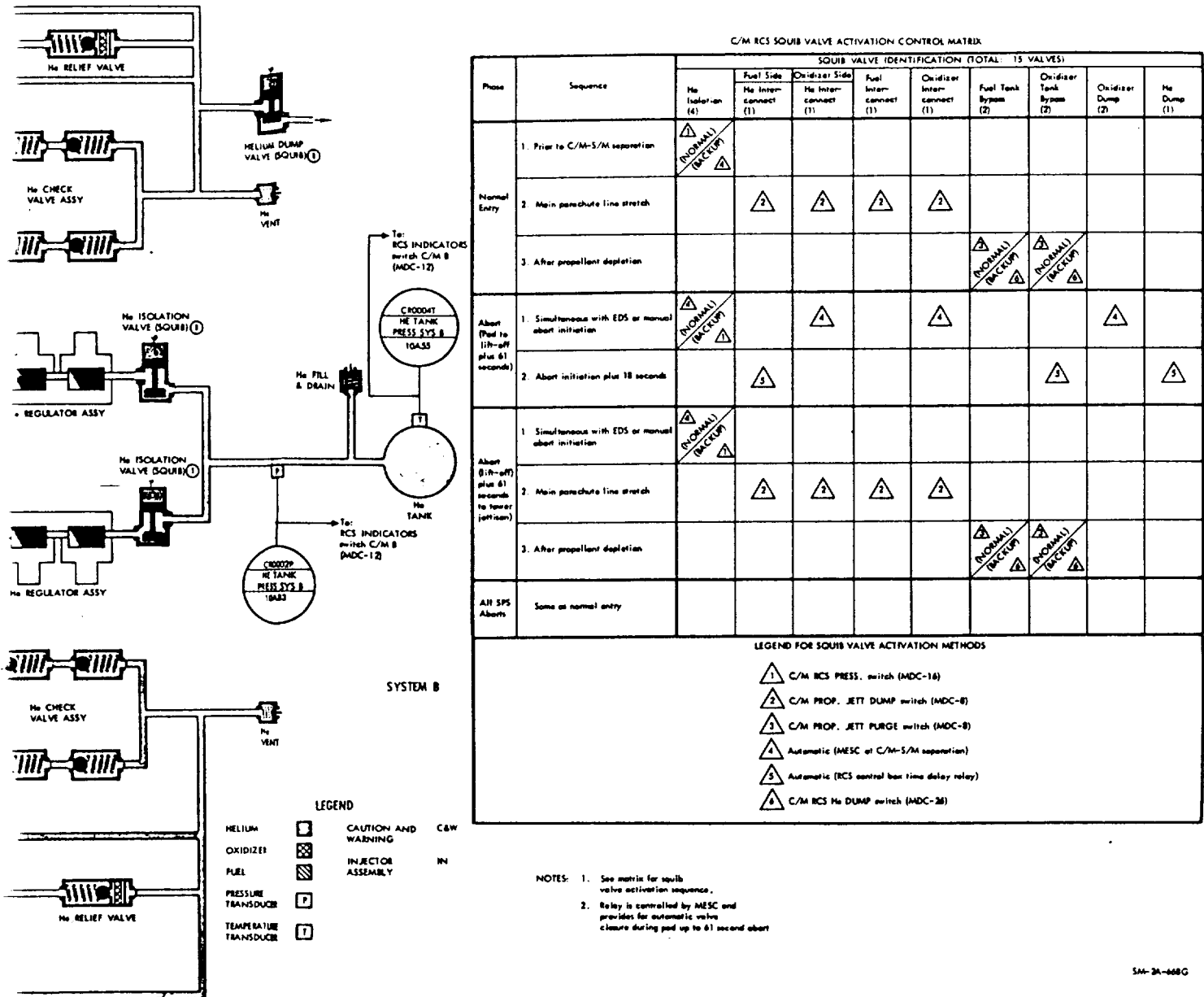


Figure 2.5-8. C/M RCS Functional Flow Diagram

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2.5.8.1 Pressurization Subsystem.

This subsystem consists of a helium supply tank, two dual-pressure regulator assemblies, two check valve assemblies, two pressure-relief valve assemblies, and associated distribution plumbing.

2.5.8.1.1 Helium Supply Tank.

The total high-pressure helium is contained within a single spherical storage tank. Initial fill pressure is  $4150 \pm 50$  psig. The limit working pressure is 5000 psig to accommodate pressure transients during filling. The proof pressure is 6667 psig and burst pressure is 7500 psig.

2.5.8.1.2 Helium Isolation (Squib-Operated) Valve.

The two squib-operated helium isolation valves are installed in the plumbing from each helium tank to confine the helium to as small an area as possible to reduce helium leakage during the period the system is not in use. Two squib valves are employed in each system to assure pressurization. The valves are opened by closure of the CM PRESS switch on panel 16, the C/M-S/M SEP switches on panel 15, or upon the receipt of an abort signal from the pad up to launch escape tower jettison.

RCS

2.5.8.1.3 Helium Pressure Regulator Assembly.

The pressure regulators used in the C/M RCS subsystems A and B are similar in type, operation, and function to those used in the S/M RCS. The differences are that the regulators in the C/M RCS are set at a higher pressure than those of the S/M RCS.

2.5.8.1.4 Helium Check Valve Assembly.

The check valve assemblies used in C/M RCS subsystems A and B are similar in type, operation, and function to those used in the S/M RCS.

2.5.8.1.5 Helium Relief Valve.

The helium relief valves used in the C/M RCS subsystems A and B are similar in type, operation, and function to those used in the S/M RCS. The differences are that the rupture pressure of the burst diaphragm in the C/M RCS is higher than that of the S/M RCS, and the relief valve relieves at a higher pressure in the C/M RCS than that of the S/M RCS.

2.5.8.1.6 Distribution Plumbing.

Brazed joint tubing is used to distribute regulated helium in each subsystem from the helium storage vessels to the propellant tanks.

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2.5.8.2      Propellant Subsystem.

Each subsystem consists of one oxidizer tank, one fuel tank, one oxidizer and fuel isolation valve, and associated distribution plumbing.

2.5.8.2.1    Oxidizer Tank.

The oxidizer supply is contained in a single, titanium alloy, hemispherical-domed, cylindrical tank to each system. Each tank contains a diffuser tube assembly and a teflon bladder for positive expulsion of the oxidizer similar to that of the S/M RCS tank assemblies. The difference is the C/M RCS tank assemblies are smaller in size. The bladder is attached to the diffuser tube at each end of the tank. The diffuser tube acts as the propellant outlet.

When the tank is pressurized, the helium gas surrounds the entire bladder, exerting a force which causes the bladder to collapse about the propellant, thus forcing the oxidizer into the diffuser tube assembly and out of the tank outlet into the manifold. Working pressure is 360 psig; proof pressure is 480 psig; and the burst pressure is 540 psig.

Fuel Tank. The fuel supply is contained in a single, titanium alloy, hemispherical-domed, cylindrical tank for each system that is similar in material, construction, and operation to that of the oxidizer tank.

2.5.8.2.2    Diaphragm Burst Isolation Valve.

The burst diaphragms, downstream from each tank are installed to confine the propellants into as small an area as possible throughout the mission. This is to prevent loss of propellants in the event of line rupture downstream of the burst diaphragm or injector valve leakage.

When the helium isolation squib valves are initiated open, regulated helium pressure pressurizes the propellant tanks, creating the positive expulsion of propellants into the respective manifolds to the burst diaphragms, which rupture, allowing the propellants to flow through the propellant isolation valves, to the injector valves on each engine. The diaphragm is of the nonfragmentation type; but, in the event of any fragmentation, a filter is incorporated to prevent any fragments from entering the engine injector valves.

2.5.8.2.3    Propellant Isolation Shutoff Valves.

When the burst diaphragm isolation valves are ruptured, the propellants flow to the propellant isolation valves.

The isolation valves in the fuel and oxidizer lines are both controlled by a single switch on panel 15. The valves are two-solenoid valves and are

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magnetically latched open and spring-loaded closed. The valves are normally open in respect to fluid flow. The C/M propellant switches A and B on panel 15 will be placed to ON after T + 61 seconds and will remain in that position until orbit insertion to ensure that the propellant isolation valves remain open when systems A and B are pressurized upon abort initiation. The switches will also be placed to ON prior to C/M-S/M separation and remain in that position until completion of propellant jettison to again ensure that the valves remain in the open position. The switches are placed to center-neutral position after tower jettison until prior to C/M-S/M separation, removing electrical power from the valves.

Each valve contains a position switch which is in parallel to one position indicator below the switch on panel 15 that controls both valves. When the position switch in each valve is open, the indicator on panel 15 is grey (same color as the panel), indicating to the crew the valves are in the normal position. When the position switch in each valve or one valve is closed, the indicator on panel 15 is diagonal lines, indicating to the crew the valve or valves are closed. The valves are closed in the event of a failure downstream of the valves, line rupture, or runaway thruster, etc. The valve will operate at 0 to 360 psig at both the inlet and outlet ports.

RCS

The proof pressure is 540 psig and the burst pressure is 720 psig. The solenoid is a 28-vdc type with a pull-in voltage of not more than 15 volts dc, and the current not to exceed 2 amperes at 30 volts dc. The valve assembly response is 200 milliseconds maximum for one-cycle operation (open-to-closed or closed-to-open).

2.5.8.2.4 Distribution Plumbing.

Brazed joint tubing is used to distribute pressurized helium gas to the propellant positive expulsion tanks in system A and system B. The distribution lines contain 11 explosive-operated (squib) valves which permit changing the helium distribution configuration to accomplish various functions within the C/M RCS. Each squib valve is actuated by an explosive charge detonated by an electrical hotwire igniter. After ignition of the explosive device, the valve remains open permanently. Two squib valves are utilized in each system to isolate the high-pressure helium gas supply to the storage tanks until RCS pressurization is commanded. Two squib valves are utilized to interconnect system A and system B regulated helium supply, which ensures pressurization of both systems during dump-burn and helium purge operations. Two squib valves in each system permit helium gas to bypass the propellant tanks, allowing helium purging of the propellant subsystem. One squib valve is installed in system B regulated helium line to permit helium depressurization in the event of a low-altitude abort (pad to T + 61 second abort).

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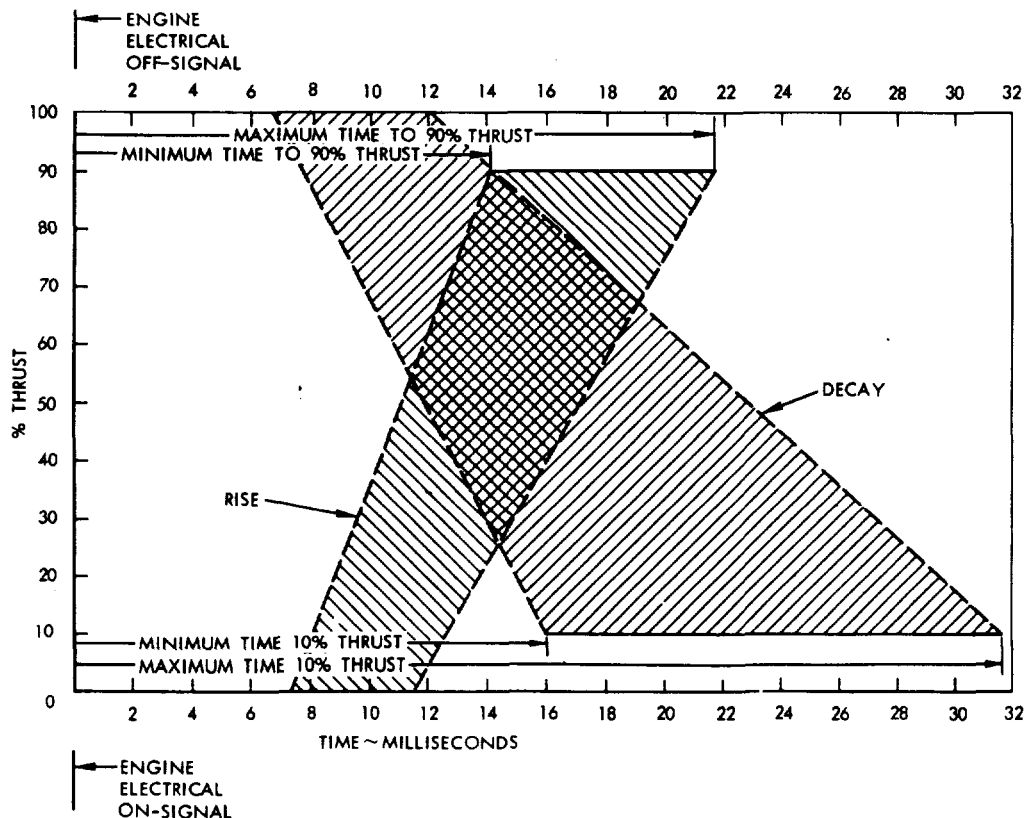
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2.5.8.3 Engine Assembly.

The command module reaction control subsystem engines are ablation cooled, bipropellant thrust generators which can be operated in either the pulse-mode or the steady-state mode.

Each engine consists of a fuel and oxidizer control valve, which controls the flow of propellants by responding to electrical commands (automatic) generated by the guidance and navigation subsystem and/or stabilization control subsystem or by the crew (manually) and an injector head assembly which directs the flow of each propellant from the propellant control valves to the combustion chamber and the combustion chamber in which the propellants are burned to produce thrust. Estimated engine thrust rise and decay is shown in figure 2.5-9.



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Figure 2.5-9. C/M RCS Engine Thrust Rise and Decay Time (Typical)

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2.5.8.3.1 Propellant Solenoid Injector Control Valves (Fuel and Oxidizer).

The injector valves utilize two coaxially wound coils: one for automatic and one for direct manual control. The automatic coil is used when the thrust command originates from the jet selection logic. The manual coils are used when the thrust command originates at the rotation control (direct mode).

The solenoid valves are spring-loaded closed and energized open. The reaction time of the valves, pulse mode of operation, reason for pulse mode, and thrust curve generated by the engine is similar to the S/M RCS engines.

The automatic coils in the fuel and oxidizer injector valves are connected in parallel from the SCS. The manual coils in the fuel and oxidizer injector valves provide a manual direct backup to the automatic system. The manual coils are connected in parallel from the rotation controls.

RCS

Engine injector valve opening time of  $5 \pm 2$  milliseconds and closing of  $6 \pm 2$  milliseconds for the automatic coils and opening time of 7 milliseconds and closing of 16 to 18 milliseconds for the direct manual coils. The actuation time shall not vary by more than +50 or -25 percent operating time between +40 to +200°F.

2.5.8.3.2 Injector.

The injector, contains a fuel and oxidizer passage that impinge (unlike impingement) upon a splash plate within the combustion chamber. Therefore, the injector pattern is referred to as an unlike impingement splash-plate injector. There are 16 fuel and 16 oxidizer passages in the injector face.

2.5.8.3.3 Thrust Chamber Assembly.

The thrust chamber assembly is fabricated in four segments: the combustion chamber ablative sleeve, the throat insert, the ablative material, and the asbestos and the fiberglass wrap. The engine is ablative cooled.

2.5.8.3.4 Nozzle Extension.

The C/M RCS engines are mounted within the structure of the C/M. The nozzle extensions are required to transmit the gases from the engine out through the structure of the C/M. The nozzle extensions are fabricated of ablative material.

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2.5.8.3.5 Engine Solenoid Injector Valve Temperature Control System.

A temperature control system of the C/M RCS engine valves is employed by energizing the manual direct coils on each engine.

Temperature transducers are mounted on the engine injector valve oxidizer solenoids. A temperature transducer is installed on the subsystem. A counterclockwise roll oxidizer valve, negative yaw oxidizer valve, negative pitch oxidizer valve and on subsystem B positive yaw oxidizer valve, negative pitch oxidizer valve, and clockwise roll oxidizer valve. These engine injector solenoid oxidizer valves were selected as the coldest engines.

The temperature transducers have a range from  $-50^{\circ}\text{F}$  to  $+250^{\circ}\text{F}$ . The temperature transducers from the three subsystem A and B engine oxidizer injector valves provide inputs to the TEST SELECT switch on panel 200, which is located in the lower equipment bay of the command module. With the FUNCTION SELECT switch on panel 200 placed to position B and the TEST SELECT rotary switch on panel 200 placed to positions 1, 2, 3, 4, 11, and 12, respectively, the specific engine oxidizer valve temperature is monitored as a d-c voltage on the 0- to 5-vdc voltmeter. Zero vdc is equivalent to  $-50^{\circ}\text{F}$  and 5 vdc is equivalent to  $+250^{\circ}\text{F}$ .

A C/M RCS HEATER switch is located on panel 200. The C/M RCS HEATER switch is placed to the ON position when any one of the instrumented engines are below  $+64^{\circ}\text{F}$ , approximately 1.80 vdc. This must be accomplished within 26 minutes prior to C/M-S/M separation, providing the C/M propellant jettison LOGIC switch is ON. The fuel and oxidizer injector valve manual coils of all C/M RCS engines are energized open (prior to pressurization of C/M RCS subsystems A and B). A 13-minute heatup time maximum or  $100^{\circ}\text{F}$ , which is monitored on the d-c voltmeter on panel 200 as 2.50 vdc, assures engine injector valve temperature is at  $+20^{\circ}\text{F}$  minimum. If  $+100^{\circ}\text{F}$ , 2.50 vdc on the d-c voltmeter is reached from the coldest instrumented engine before 13 minutes, the C/M RCS HEATER switch is placed to OFF, which de-energizes the engine injector valves and the injector valves spring-load closed. If a time of 13 minutes is reached before  $+100^{\circ}\text{F}$ , 2.50 vdc on the d-c voltmeter, the C/M RCS HEATER switch is placed to OFF. This will prevent the oxidizer from freezing at the engine injector valves upon pressurization of subsystems A and B.

The C/M RCS HEATER switch must be placed to OFF prior to C/M RCS pressurization. The operation of the C/M RCS HEATER switch in conjunction with the d-c voltmeter and/or heating time ensures all other engine valves reach the acceptable temperature levels. The  $+100^{\circ}\text{F}$ , 2.50 vdc, or thirteen-minute time limit assures that the warmest engine valve will be less than  $+200^{\circ}\text{F}$ .

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2.5.8.3.6 Engine Thrust ON-OFF Logic.

All thrust commands for C/M attitude pass through the stabilization and control subsystem and the jet selection logic. These commands may originate at the following:

- a. The rotation controls
- b. The stabilization and control subsystem
- c. The guidance and navigation subsystem.

In the event the SCS and/or jet selection logic is unable to provide commands to the automatic coils of the C/M RCS engines, placing the DIRECT RCS switch on panel 8 to the ON position provides power to the rotation control. When the rotation control is positioned fully to its stops in any direction, the rotation control energizes the required manual coils for the desired maneuver.

When the CM SM SEP switches on panel 15 are placed to CM SM SEP position, the switches automatically energize relays in the RCS transfer panels (C19A4) and in the RCS control boxes (C19A1) (figure 2.5-10) (providing the CM PROP JETT LOGIC switch on panel 8 is ON) that transfers the SCS and direct manual inputs from the S/M RCS engine to the C/M RCS engines automatically. (These same functions occur on any LES ABORT.)

The transfer motors in the RCS transfer panels (C19A4) and in the RCS control boxes (C19A1) are redundant to each other in that they ensure the SCS and direct manual inputs are transferred from the S/M RCS engines to the C/M RCS engines. The transfer motors in the RCS control boxes (C19A1) are automatically activated by the CM SM SEP switches (providing the CM PROP JETT LOGIC switch is ON); in addition, they may also be activated by the manual backup of the RCS TRANSFER switch on panel 16. The transfer motors in the RCS transfer panels (C19A4) are activated automatically only by the CM SM SEP switches (providing the CM PROP JETT LOGIC switch is ON).

As an example, if the RCS transfer motor in C19A1 failed to transfer automatically at CM SM SEP, the RCS transfer motor in C19A4 would still automatically transfer the SCS and direct manual inputs from the S/M RCS engines to the C/M RCS engines (providing the CM PROP JETT LOGIC switch is ON). In addition, the RCS TRANSFER switch on panel 16 provides a manual backup to the C19A1 RCS transfer motors only.

Another example, the C/M RCS subsystems could be checked out prior to CM SM SEP by placing the RCS TRANSFER switch on panel 16 to CM position, and only the RCS transfer motors (C19A1) in the RCS control boxes would transfer the SCS and direct manual inputs from the S/M RCS engines to the C/M RCS engines. The transfer motors in the RCS transfer panels (C19A4) would not transfer until C/M S/M SEP (providing the C/M PROP JETT LOGIC switch is ON) and then start the SM jettison controllers.

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2.5.8.4      Propellant Jettison.

There are two sequences of propellant jettison. One sequence is employed in the event of an abort while the vehicle is on the launch pad and through the first 61 seconds of flight. The second sequence is employed for all other conditions, whether it be a normal or an abort mode of operation. The sequence of events before and during a normal re-entry is as follows:

a. The crew will place the C/M S/M SEPARATION switches to the C/M S/M SEPARATION position on panel 15 or place the C/M RCS PRESS switch on panel 16 to the ON position, prior to initiating C/M S/M separation. The C/M RCS PRESS switch or the C/M S/M SEP switches initiates the helium isolation squib valves in C/M RCS subsystems A and B, thus pressurizing both subsystems (figures 2.5-8 and 2.5-10). The C/M RCS PRESS switch provides a backup to the C/M S/M SEP switches and the RCS LOGIC switch on panel 8 must be ON, prior to initiating C/M-S/M separation to provide an automatic RCS transfer.

b. The C/M continues to descend after re-entry into the earth atmosphere. At 24,000 feet, barometric switch is activated which unlatches the RCS latching relay, inhibiting any commands from the SCS to the jet selection logic (figure 2.5-3) (manual backup of RCS CMD switch panel 16).

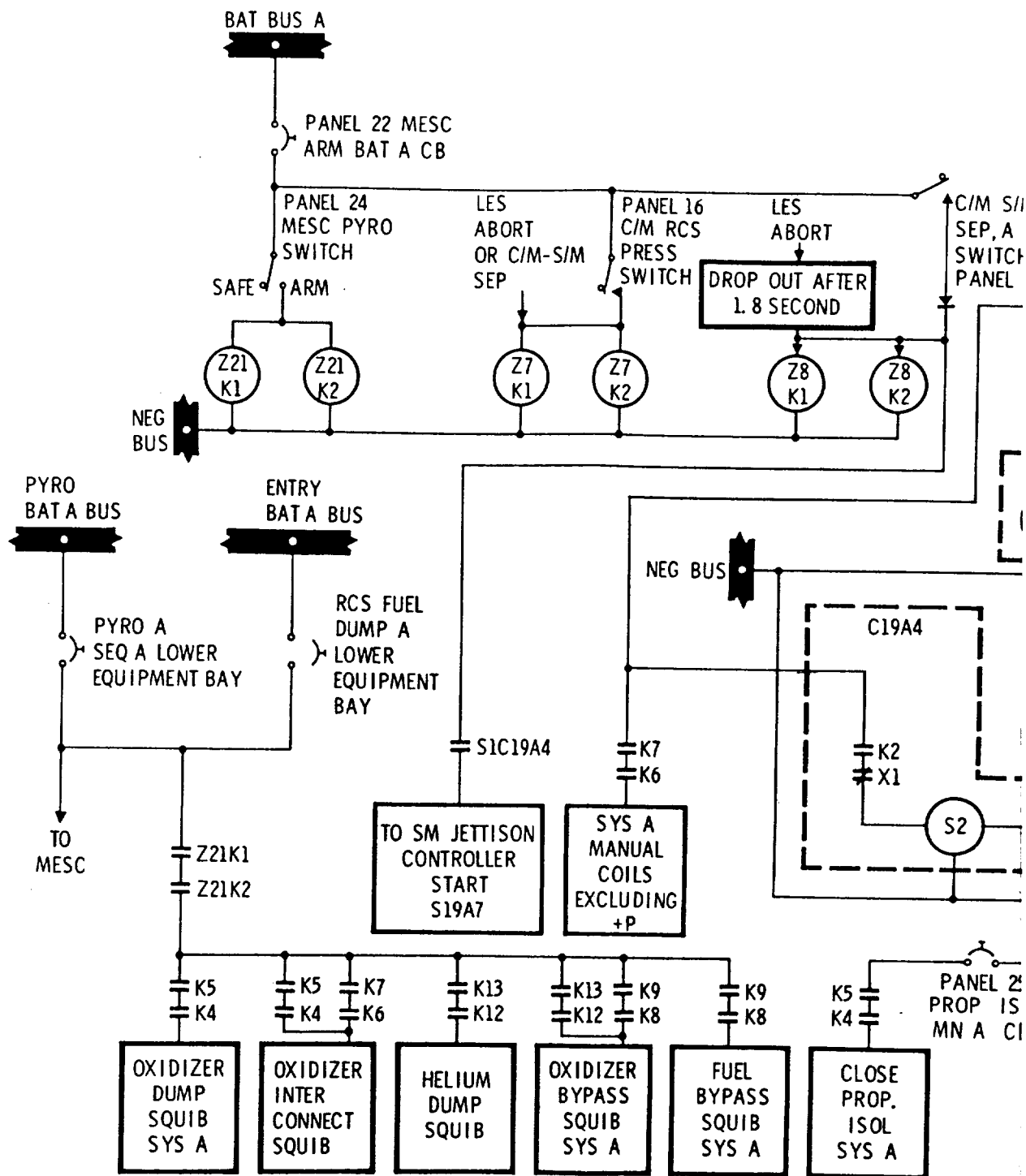
c. At main parachute line stretch, the RCS propellant jettison DUMP switch on panel 8 is placed to the DUMP position as a normal manual function by the crew, initiating the following functions, simultaneously. The RCS LOGIC switch on panel 18 must be ON prior to placing DUMP switch to DUMP position.

1. Initiates the two helium interconnect squib valves
2. Initiates the fuel interconnect squib valve
3. Initiates the oxidizer interconnect squib valve
4. The fuel and oxidizer injector valve manual coils are energized on all of the C/M RCS engines, excluding the + pitch engines. The + pitch engines are not energized due to their location being adjacent to the steam vent. The propellants are jettisoned by burning the propellants remaining in 10 of the 12 engines. The length of time to burn the remaining propellants will vary, depending upon the amount of propellants remaining in the fuel and oxidizer tanks at 24,000 feet. If an entire propellant load remained, as an example, a nominal burn time would be 88 seconds through 10 of the 12 engines. In the worst case of only 5 of the 12 engines (manual coils energized), a nominal burn time would be 155 seconds.

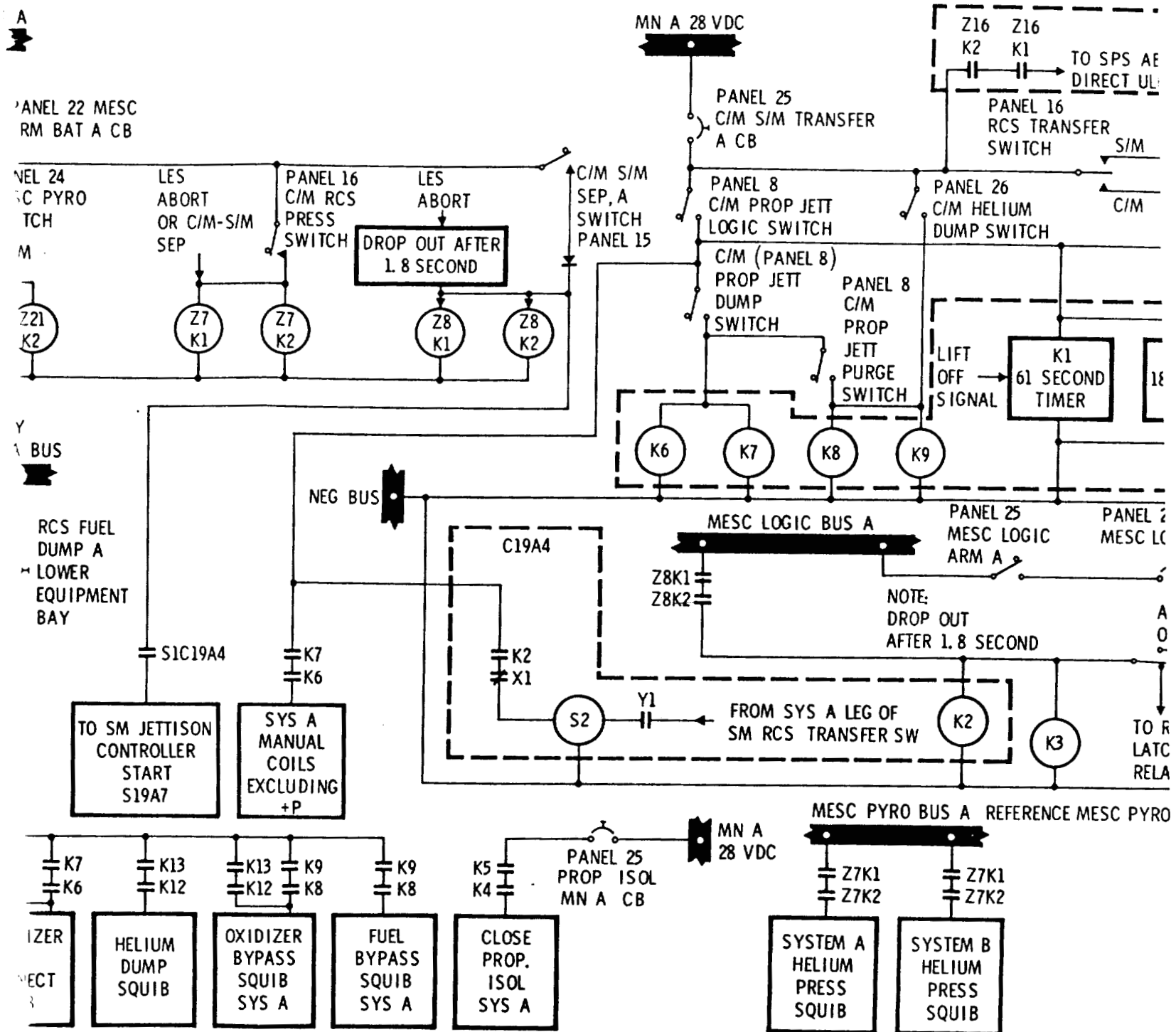
d. Upon completion of propellant burn, the C/M propellant jettison PURGE switch on panel 8 is placed to the PURGE position as a normal manual function by the crew. When the PURGE switch is on, the switch initiates the four helium bypass squib valves, allowing the regulated helium pressure to bypass around each fuel and oxidizer tank, thus purging the manifolds through 10 of the 12 engines. Purging requires approximately 15 seconds or until helium depletion.

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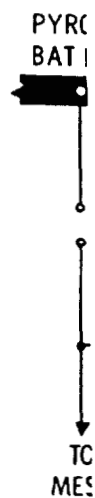
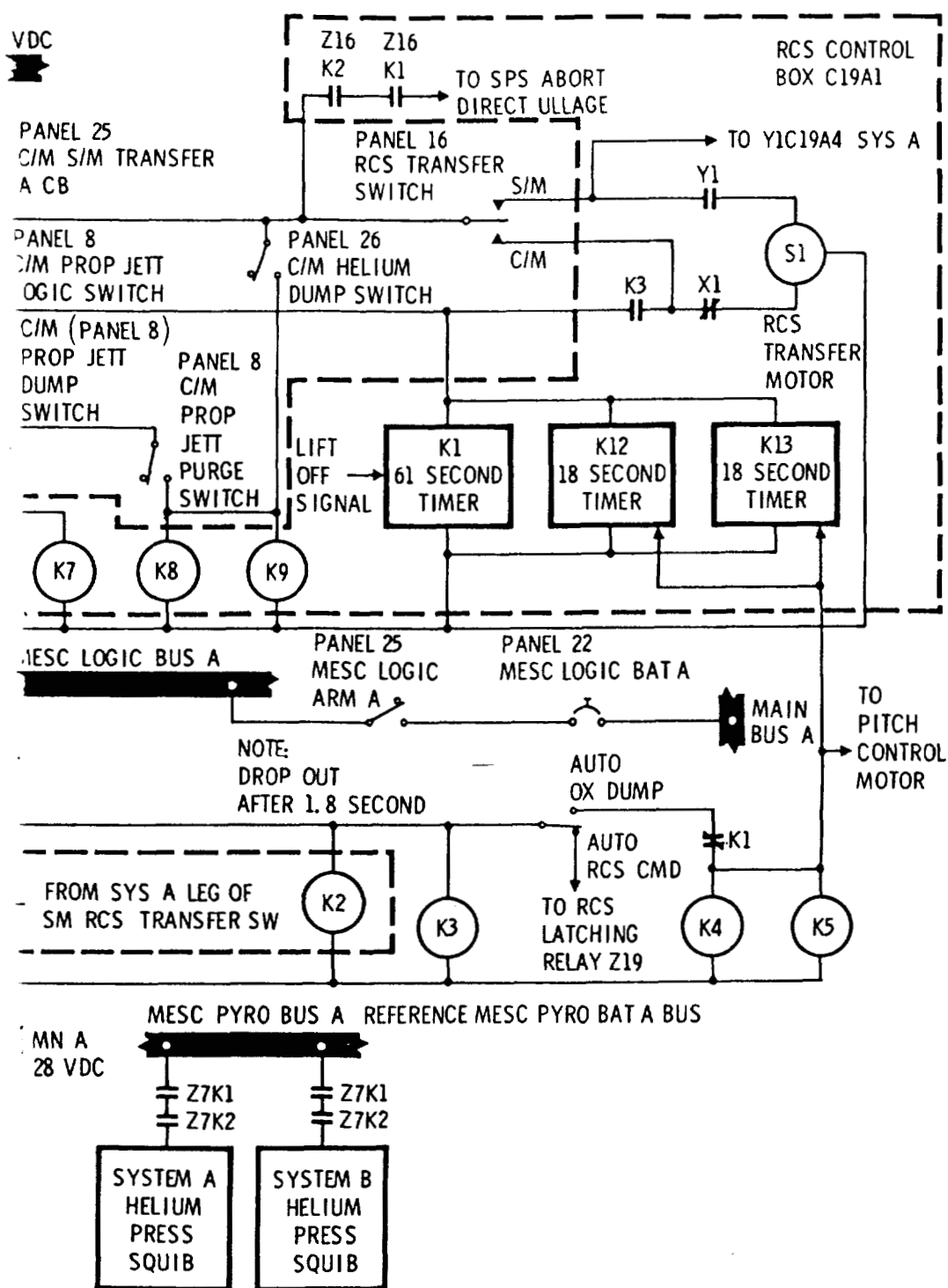
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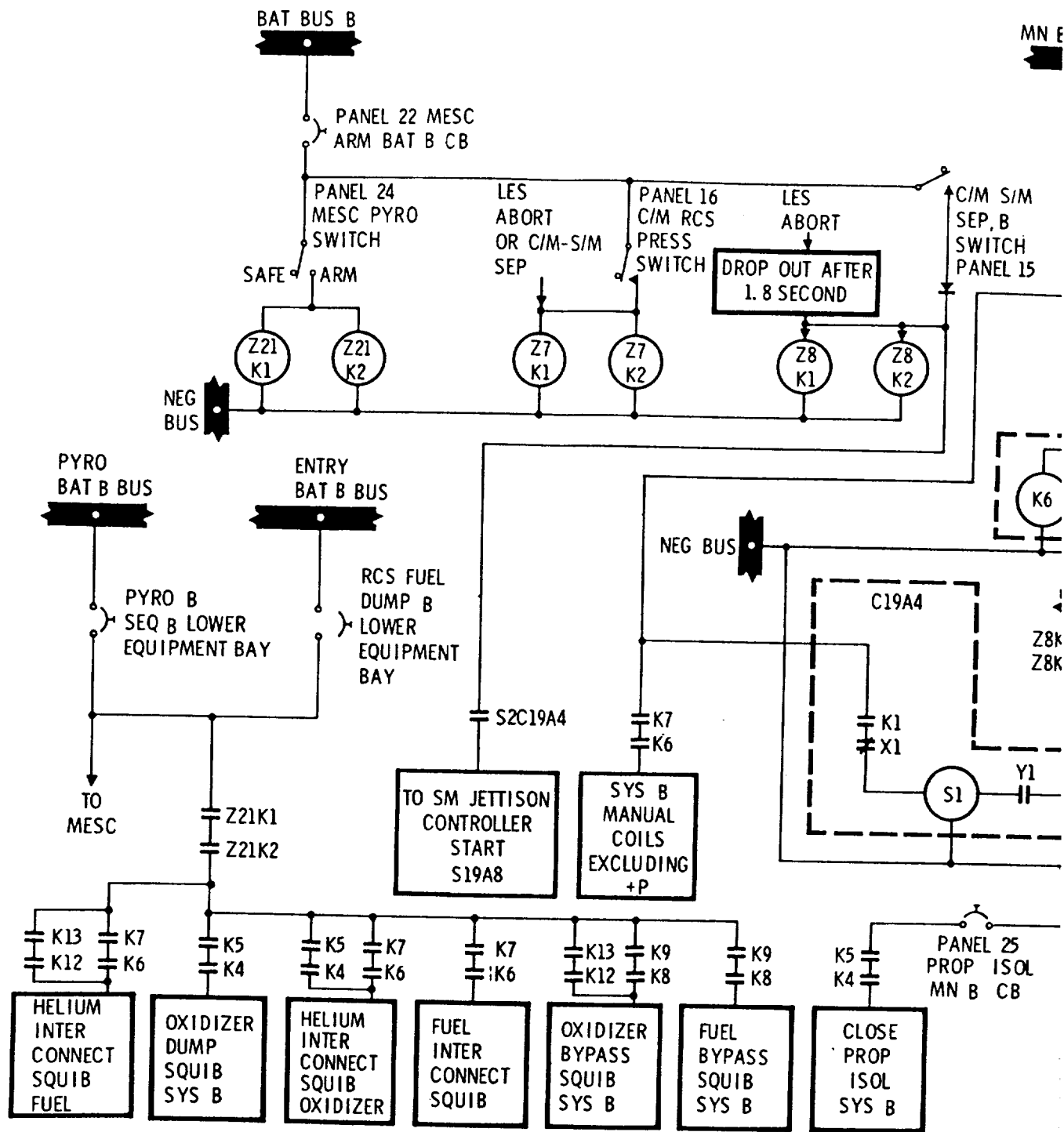
FOLDOUT FRAME

3



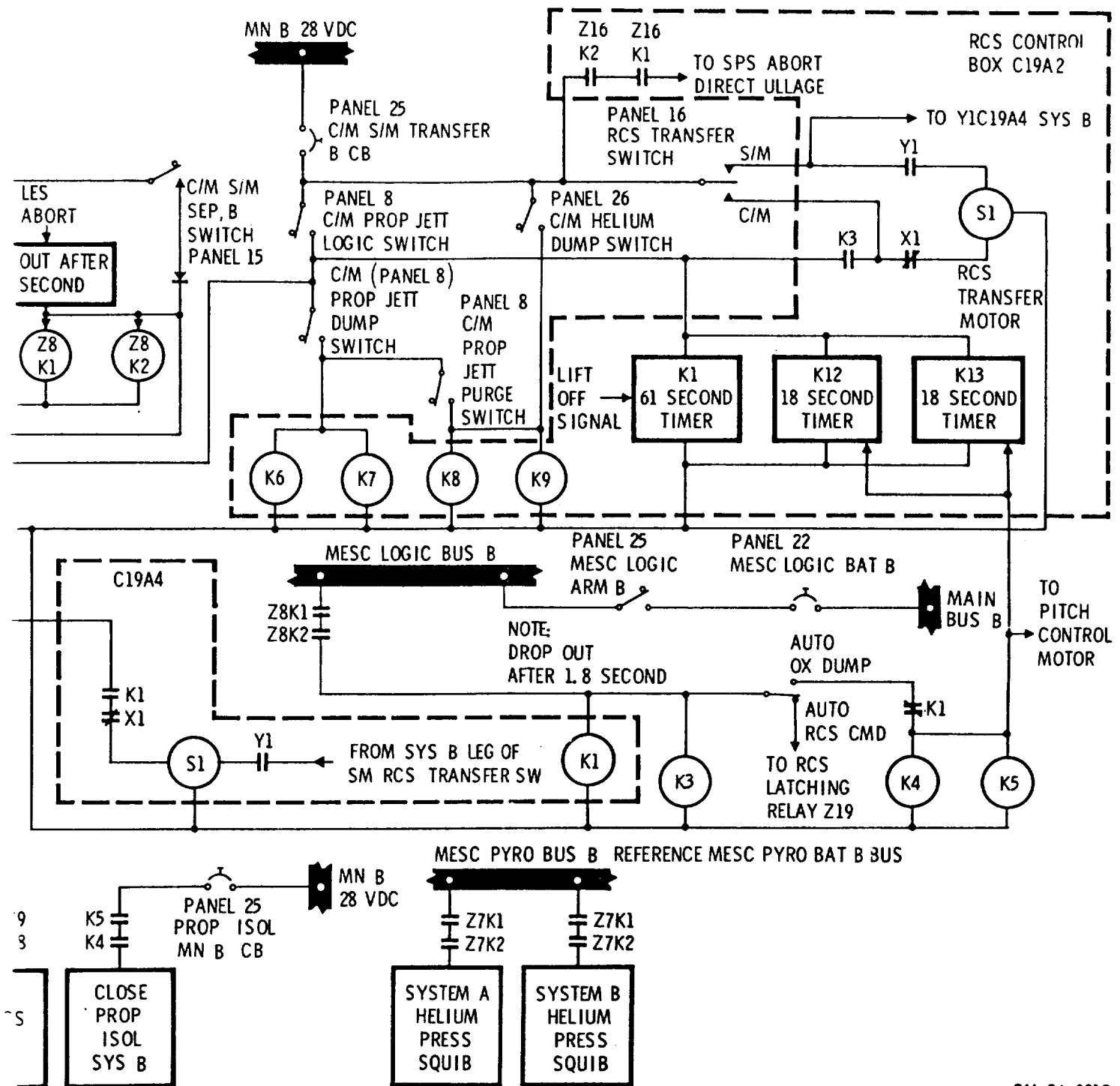








SYSTEMS DATA



SM-2A-901B

Figure 2.5-10. C/M RCS Squib Valve Power Control Diagram

REACTION CONTROL SYSTEM



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SYSTEMS DATA

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e. In the event of the C/M propellant jettison LOGIC switch and/or DUMP switch failure, the remaining propellants may be burned by placing the DIRECT RCS switch on panel 8 to ON and positioning the two rotation controllers to CCW, CW, -Y, +Y and -P (excluding +P) position, energizing the manual fuel and oxidizer injector valve solenoid coils of 10 of the 12 C/M RCS engines burned. At the completion of propellant burn, the C/M RCS HELIUM DUMP switch on panel 26 would be placed ON initiating the four bypass squib valves, allowing the regulation helium pressure to bypass around each fuel and oxidizer tank, and purging the manifolds through 10 of the 12 engines providing the two rotation controllers are positioned to CCW, CW, -Y, +Y and -P (excluding +P).

f. In the event the C/M propellant jettison LOGIC switch and DUMP switch on panel 8 function correctly and the PURGE switch fails, the C/M HELIUM DUMP switch on panel 26 would be placed to ON; thus initiating the four helium bypass squib valves, allowing the regulated helium pressure to bypass around each fuel and oxidizer tank, and purging the manifolds through 10 of the 12 engines.

g. Prior to water impact the LOGIC switch on panel 8 may be placed to the OFF position, which would de-energize the manual coils of the engine injector valves allowing the engine injector valves to spring-load closed, preventing sea water from entering the manifolds through the engine. The DUMP switch placed to the OFF position will accomplish the same function.

RCS

The sequence of events involving an abort from the pad up to 61 seconds is as follows:

a. The OXIDIZER DUMP switch on panel 16 is placed in the AUTO OX DUMP position, and the RCS LOGIC switch on panel 8 is placed in the ON position at some time in the countdown prior to T=0.

b. The following events occur simultaneously upon the receipt of the abort signal. The command may be generated automatically by the sequence events controller subsystem or by manually rotating the translation control counterclockwise.

1. When the abort signal is received, the two squib-operated helium isolation valves in each system are initiated open, pressurizing subsystems A and B. Manual backup of the C/M PRESS switch, panel 16.

2. The squib-operated helium interconnect valve for the oxidizer tanks is initiated open. If only one of the two squib helium isolation valves was initiated open, both systems are pressurized as a result of the helium interconnect squib valve interconnect.

3. The solenoid-operated fuel and oxidizer isolation shutoff valves are closed to prevent fuel and oxidizer from flowing to the thrust chamber assemblies.

4. The squib-operated oxidizer interconnect valve is initiated open. If only one of the two oxidizer overboard dump squib valves was initiated open, the oxidizer manifolds of each system are common as a result of the oxidizer interconnect squib valve.

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REACTION CONTROL SYSTEM

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SYSTEMS DATA

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5. The squib-operated oxidizer overboard dump valves route the oxidizer to a blow-out plug in the aft heat shield of the C/M which shears a pin due to the pressure buildup and blows the plug out, dumping the oxidizer overboard. The entire oxidizer supply is dumped in approximately 13 to 15 seconds.

6. The RCS latching relay will not energize in the event of an abort from 0 to +61 seconds due to the position of the AUTO OX DUMP switch (figures 2.5-3 and 2.5-10). Thus, no commands are allowed into the jet selection logic from the SCS.

7. The C/M-S/M RCS transfer motor-driven switches are automatically driven upon the receipt of the abort signal, allowing electrical signals to be supplied to the C/M RCS engine injector valves. Manual backup of RCS transfer switch, panel 16.

c. Eighteen seconds after the abort signal is initiated, the following events automatically occur simultaneously:

1. The helium interconnect squib valve between the fuel tanks is initiated open.

2. The helium overboard dump squib valve is initiated open, dumping the helium pressure overboard into the aft equipment compartment, releasing the helium pressure from both fuel tanks.

3. The bypass squib valve to the subsystems A and B oxidizer tank is initiated open, purging both oxidizer systems out through the overboard dump in the aft heatshield.

4. Fuel remains onboard at impact with no pressure on the fuel tanks.

The sequence of events of an abort, initiated after 61 seconds up to launch escape tower jettison, are as follows:

a. At 61 seconds after lift-off, the crew as a normal manual function will place the AUTO OX DUMP switch on panel 16 to the AUTO RCS CMD position.

b. The RCS LOGIC switch was placed to the ON position prior to T+0.

1. Initiate both helium isolation squib valves in C/M RCS, subsystems A and B. Manual backup of C/M RCS PRESS switch on panel 16; thus, pressurizing C/M RCS subsystems A and B.

2. Drives the C/M S/M RCS transfer motors to the C/M RCS position. Manual backup of RCS TRANSFER switch on panel 16 for C19A1 RCS transfer motors only.

3. RCS latching relay energized one second after receipt of the abort signal.

d. At main parachute line stretch, as a normal manual function, the RCS propellant and jettison DUMP switch on panel 8 is placed to the DUMP position initiating functions the same as a normal entry.

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SYSTEMS DATA

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2.5.9 C/M RCS PERFORMANCE AND DESIGN DATA.

2.5.9.1 Design Data.

The following list contains data of the CM/RCS components:

HELIUM TANKS (2)	4150±50 psig at 70°±5°F during servicing, setting on launch pad 70°±10°F. Capacity 0.57 lbs, inside diameter 8.84 in., wall thickness 0.105 in. and internal volume of 365±5 cubic in. at 4150±50 psig.
HELIUM ISOLATION SQUIB VALVE FILTER	Remove 98 percent of all particles whose two smallest dimensions are greater than 40 microns.  Remove 100 percent of all particles whose two smallest dimensions are greater than 74 microns.
REGULATOR UNITS (4)	Primary - Initial of 291±6 psig and stabilize within 2 seconds to 291±4 psig. Lockup pressure minimum of 284 psig and not exceed 302 psig.  Secondary - Lockup 287 to 308 psig and stabilize at 294.5±7.5 psig within 2 seconds.
HELIUM RELIEF VALVES (4)	Diaphragm rupture at 340±8 psi  Filter - 10 microns nominal, 25 microns absolute  Relief valves relieves at 346±14 psig  Relief valve reseats at no less than 327 psig  Flow capacity 0.3 lb/min at 60°F and 346±14 psig  Bleed device closes when increasing pressure has reached no more than 179 psig in the cavity and a helium flow of less than 20 standard cubic centimeters per hour across the bleed and relief valve assemblies combined. The bleed device shall reopen when decreasing pressure has reached no less than 20 psig.

RCS

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PRESSURE TRANSDUCERS FUEL AND OXIDIZER	illuminates caution and warning light on panel 10 (C/M RCS A or B)  After helium isolation, underpressure 265 psia  Squib valve actuation, overpressure 325 psia
FUEL TANKS (2)	Combined propellant and ullage volume of 45.2 lbs, initially at 65°F at 30±2 psig, resulting in a tank pressure of no more than 205 psia when heated to 105°F. Length 17.329 (+0.040, -0.000) in., outside diameter maximum 12.62 in., wall thickness 0.022 in. to 0.027 in.
OXIDIZER TANK (2)	Combined propellant and ullage volume of 89.2 pounds initially at 65°F at 30±2 psig, resulting in a tank pressure of no more than 205 psia when heated to 85°F. Length 19.907 (+0.040, -0.000) in., maximum outside diameter 12.62 in., wall thickness 0.022 to 0.027 in.
VALVE ISOLATION BURST DIAPHRAGM (4)	Rupture at 241±14 psig, within 2 seconds after rupture pressure is reached at any temperature between 40° to 105°F.  Filter 75 microns nominal, 100 microns absolute.
ENGINE	200-second service life, 3000 operational cycles  Nominal thrust, 93 pounds  Expansion ratio, 9 to 1  Cooling, ablation  Injector type, 16 on 16 splash plate  Combustion chamber refrasil ablative sleeve and graphite base throat insert.

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REACTION CONTROL SYSTEM



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SYSTEMS DATA

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Automatic and manual coils - connected  
in parallel

Weight, 8.3 lbs

Length, 11.65 in. maximum

Nozzle exit diameter, 2.13 inches

Nozzle extensions, ablative refracil

OXIDIZER DUMP BLOWOUT PLUG      Pin shears at 100 psig

2.5.9.2      Performance Data.

Refer to Mission Modular Data Book, SID 66-1177.

2.5.9.3      Power Consumption Data.

Refer to paragraph 2.5.4.3.

2.5.10      C/M RCS OPERATIONAL LIMITATIONS AND RESTRICTIONS.

A propellant isolation valve switch must be placed to ON momentarily prior to lift-off and returned to neutral. At T+61 seconds after lift-off the switches must be placed to ON until orbit insertion to ensure that the valves will remain open if an LES abort is initiated; then at orbit insertion, the switches may be placed to neutral. The switches must be placed to ON prior to C/M RCS pressurization to ensure valves remain open throughout entry.

2.5.10.1      C/M RCS Electrical Power Distribution.

See figure 2.5-11 for electrical power distribution.

2.5.11      C/M RCS TELEMETRY MEASUREMENTS.

The following is a complete list of the C/M RCS telemetry data that is monitored by the flight controllers and ground support personnel.

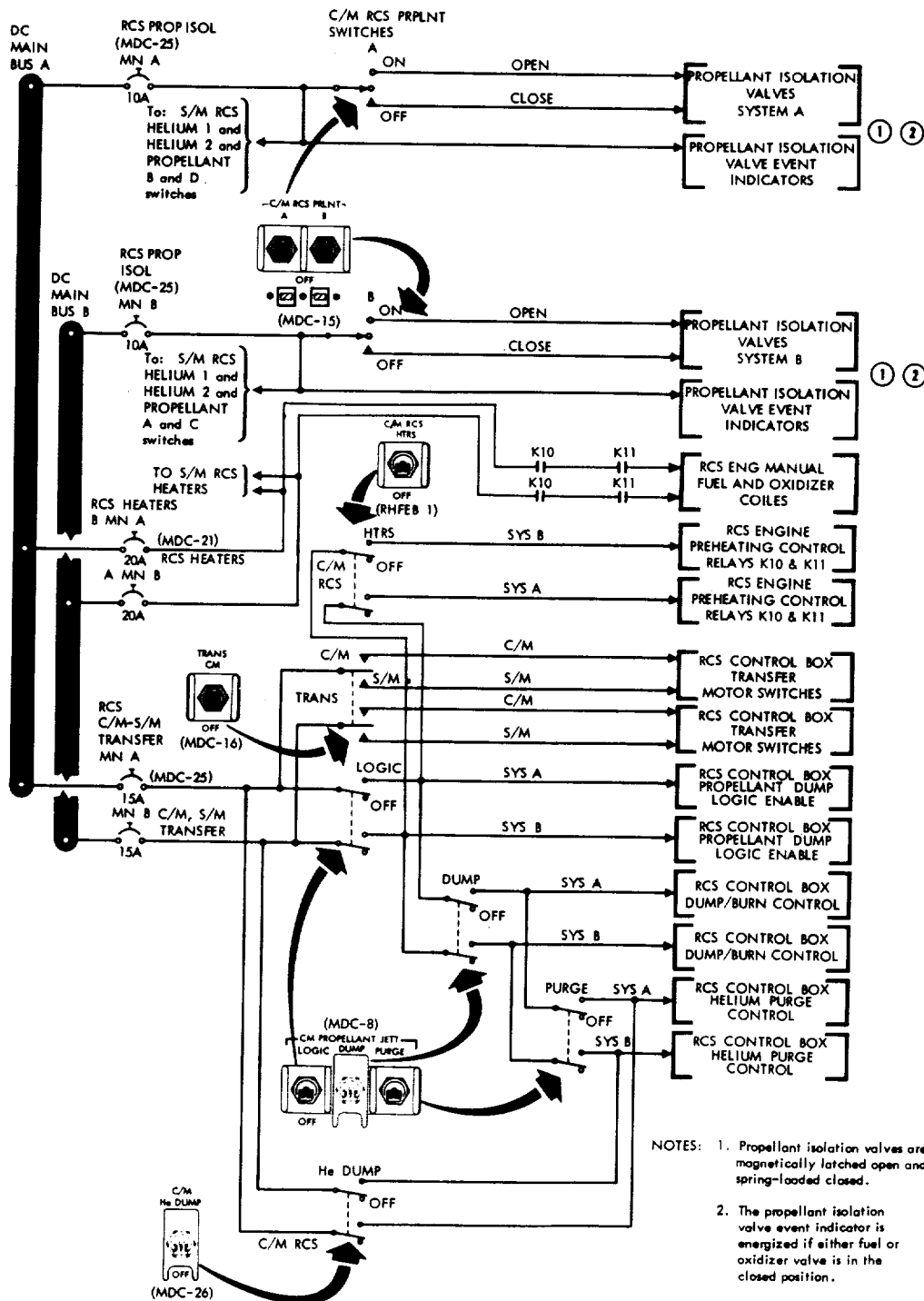
RCS

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REACTION CONTROL SYSTEM

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SYSTEMS DATA



SM-2A-714C

Figure 2.5-11. C/M RCS Electrical Power Distribution Diagram

REACTION CONTROL SYSTEM

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SYSTEMS DATA

Crew Display	Figure	Measurement	Measure- ment Number	Range	Signal Conditioner	Channel Code*	Bit Rate*	*	Operating Range
Panel 12	2.5-7	Helium Tank Supply Pressure A	CR0001P	+0 +5K psia	C28AR31	10A81	H2	PCM	4150±50 psia and decrease during mission.
Panel 12	2.5-7	Helium Tank Supply Pressure B	CR0002P	+0 +5K psia	C28AR32	10A83	H2	PCM	
Panel 12	2.5-7	Helium Tank Supply Temperature A	CR0003T	+0 +300°F	C28AR33	10A52	H1	PCM	70±10°F on launch pad variable during mission.
Panel 12	2.5-7	Helium Tank Supply Temperature B	CR0004T	+0 +300°F	C28AR34	10A55	H1	PCM	
Panels 10 and 12	2.5-7	Fuel Tank A Pressure	CR0005P	+0 +400 psia	C28AR35	11A107	H2	PCM	
Panels 10 and 12	2.5-7	Fuel Tank B Pressure	CR0006P	+0 +400 psia	C28AR36	11A114	H2	PCM	After pressurization 287 to 308 psia until propellant purge
Panels 10 and 12	2.5-7	Oxidizer Tank A Pressure	CR0011P	+0 +400 psia	C28AR38	11A79	H2	PCM	
Panels 10 and 12	2.5-7	Oxidizer Tank B Pressure	CR0012P	+0 +400 psia	C28AR39	11A81	H2	PCM	
	2.5-7	Fuel Line Pressure A	CR0623P	+0 +400 psia		F-1		FQ	
	2.5-7	Fuel Line Pressure B	CR0624P	+0 +400 psia		F-2		FQ	
	2.5-7	Oxidizer Line Pressure A	CR0625P	+0 +400 psia		F-3		FQ	
	2.5-7	Oxidizer Line Pressure B	CR0626P	+0 +400 psia		F-4		FQ	
Panel 97	2.5-7	Temperature Oxidizer Valve CCW R Engine A	CR2201T	-50 +250°F	C28AR295	51A17	H1	PCM	Flight recorder.
Panel 97	2.5-7	Temperature Oxidizer Valve -Y Engine A	CR2202T	-50 +250°F	C28AR296	11A78	H1	PCM	
Panel 97	2.5-7	Temperature Oxidizer Valve -P Engine A	CR2205T	-50 +250°F	C28AR299	51A18	H1	PCM	Variable during mission, prior to separation turn heaters on if below +64°F, turn off in 13 minutes time or 100°F, whichever is reached first.
Panel 97	2.5-7	Temperature Oxidizer Valve +Y Engine B	CR2203T	-50 +250°F	C28AR297	10A35	H1	PCM	
Panel 97	2.5-7	Temperature Oxidizer Valve -P Engine B	CR2204T	-50 +250°F	C28AR298	10A38	H1	PCM	
Panel 97	2.5-7	Temperature Oxidizer Valve CWR Engine B	CR2206T	-50 +250°F	C28AR300	10A34	H1	PCM	
	2.5-7	CCW Roll Engine Chamber Pressure A	CR0514P	+0 +250 psia		F-13		FQ	
	2.5-7	CCW Roll Engine Chamber Pressure B	CR0520P	+0 +250 psia		F-14		FQ	
	2.5-7	CCW Roll Engine Wall Temperature A	CR4561T	+0 +1000°F		51A19	H1	FQ	Variable

RCS

REACTION CONTROL SYSTEM

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SYSTEMS DATA

Crew Display	Figure	Measurement	Measurement Number	Range	Signal Conditioner	Channel Code*	Bit Rate*	*	Operating Range
	2.5-7	CCW Roll Engine Wall Temperature B	CR4582T	+0 +1000°F		51A20	H1	FQ	Variable
	2.5-9	C/M-S/M SEP Relay Close A (Z9 to Z7)	CD0023X	OFF ON event		11E12-03	E2	PCME	Event
	2.5-9	C/M-S/M SEP Relay Close B (Z9 to Z7)	CD0024X	OFF ON event		11E12-04	E2	PCME	Event
	2.5-9	LES Abort Initiate Signal A (Z9 to Z7)	CD0002X	OFF ON event		11E12-01	E2	PCME	Event
	2.5-9	LES Abort Initiate Signal B (Z9 to Z7)	GD0062X	OFF ON event		11E12-07	E2	PCME	Event
	2.5-9	RCS Actuate Signal A (Z19)	CD0170X	OFF ON event		11E13-06	E2	PCME	Event
	2.5-9	RCS Activate Signal B (Z19)	CD0171X	OFF ON event		11E13-07	E2	PCME	Event
	2.5-9	C/M Pressurize Signal A (Z9 to Z7)	CD0173X	OFF ON event		11E13-08	E2	PCME	Event
	2.5-9	C/M Pressurize Signal B (Z9 to Z7)	CD0174X	OFF ON event		11E14-01	E2	PCME	Event
	2.5-9	Barometric Switch Lock In Close Relay A	CE0007X	CLOSE OPEN event		11E14-08	E2	PCME	Event
	2.5-9	Barometric Switch Relay Lock In Close Relay B	CE0008X	CLOSE OPEN event		11E15-01	E2	PCME	Event
	2.5-9	Lift-Off Signal A	BS0060X			11E25-03	E2	PCME	Event
	2.5-9	Lift-Off Signal B	BS0061X			11E25-04	E2	PCME	Event
<p>*Analog measurements digitally coded into 8 bit words.            Analog measurements -0 (+0.15 -0) vdc to 5 (+0, -0.15) vdc            FQ - Flight qualification measurements            H1 - High bit rate            H2 - High and low bit rate            E2 - High and low bit rate</p> <p>Channel Example: 10A81</p> <p>Significant number - 1 }            How many zeros after significant number is amount of samples per second } 0            1 sample per second</p>									

REACTION CONTROL SYSTEM

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SYSTEMS DATA

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SECTION 2

SUBSECTION 2.6

ELECTRICAL POWER SYSTEM (EPS)

2.6.1 INTRODUCTION.

The electrical power system (figure 2.6-1) supplies all electrical power required by the spacecraft to complete its scheduled mission. D-C electrical power is provided by three fuel cell power plants, two S/M jettison controller batteries located in the service module, and five batteries (2 pyro and 3 entry) located in the command module. A-C electrical power is provided by one, or two, of the three inverters located in the lower equipment bay of the command module. Controls and displays for the EPS are positioned in the command module near the astronaut responsible for controlling and monitoring the system. The EPS can be divided into four subsystems as follows:

- Energy storage: cryogenic storage; pyrotechnic, entry, and S/M jettison controller batteries
- Power generation: fuel cell power plants
- Power conversion: solid state inverters, battery charger
- Power distribution: d-c power distribution, a-c power distribution, sensing circuits, controls and displays.

EPS

2.6.2 FUNCTIONAL DESCRIPTION.

2.6.2.1 Energy Stowage.

The primary source of energy for the EPS is provided by the cryogenic storage system. There are two hydrogen (fuel) and two oxygen (oxidizer) cryogenic storage tanks. Each tank has its associated controls, heaters, and fans designed to give, in an automatic mode, a single-phase reactant to its load throughout the tank-density range, when operating at normal pressures.

A secondary source of energy storage is provided by batteries. The batteries supply sequencer logic and pyro power at all times, supplemental d-c power for high-peak loads, and all electrical power required during the entry and postlanding phases after CSM separation.

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ELECTRICAL POWER SYSTEM

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SYSTEMS DATA

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2.6.2.2      Power Generation.

Three Bacon-type fuel cell power plants in the service module generate the d-c power required for spacecraft systems. The fuel cell power plants are activated prior to launch and operate continuously throughout the mission until CSM separation. Normally, fuel cell power plant 1 is connected to main d-c bus A, power plant 3 to main d-c bus B, and power plant 2 to both main d-c buses A and B. However, the capability is provided to also connect fuel cell power plant 1 to main d-c bus B and fuel cell power plant 3 to main d-c bus A.

Each fuel cell is rated to produce  $29 \pm 2$  volts dc between 563 and 1420 watts of power. Two fuel cell power plants are capable of providing the normal power requirements of all spacecraft systems. If two fuel cell power plants malfunction, some of the electrical components must be shut down to conserve power, and the remaining power plant with battery backup will supply sufficient power to carry the load and insure successful mission termination. One fuel cell with complete battery backup can provide maximum power required by mission burns, if the cryogenics are available and fuel cell temperature is above 425°F.

2.6.2.3      Power Conversion.

Primary d-c power is converted into a-c power by solid-state inverters. The inverters provide 115-volt 400-cps 3-phase a-c power up to 1250 volt-amperes each. The a-c power is connected to the two a-c buses which supply power to a-c loads. During normal operation, one inverter will power both a-c buses while the two remaining inverters act as redundant sources. For peak loads, each a-c bus will be powered by a separate inverter. In case of an a-c or d-c bus failure, the inverters and remaining buses can be isolated. Inverter switching circuits prevent connecting two inverters on one bus, but simultaneous operation of two inverters is possible if each is connected to a separate bus. A phase synchronizing unit provides in-phase power when a separate inverter is powering each bus.

The battery charger is a secondary power conversion unit, which is used to keep entry batteries charged. The charger is a solid-state device converting a-c power from the inverters and using d-c power from the fuel cells to provide charging voltage.

2.6.2.4      Power Distribution.

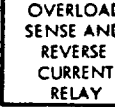
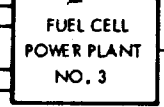
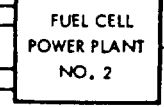
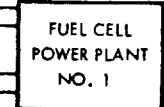
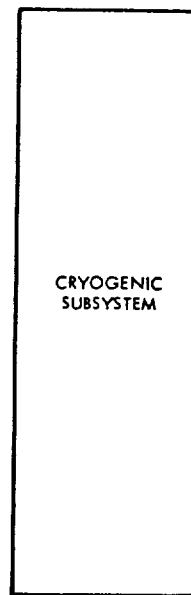
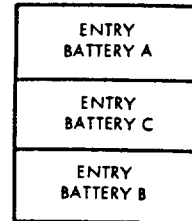
Distribution of primary d-c power is accomplished by two redundant d-c buses in the command module. Additional buses consist of two separate nonessential buses for servicing nonessential loads, a battery relay bus for power distribution switching, two battery buses, and a flight and postlanding bus to service certain communications and the postlanding circuits. A-C power is distributed by two redundant a-c buses.

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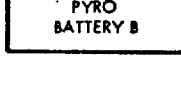
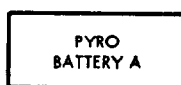
ELECTRICAL POWER SYSTEM

# ENERGY STORAGE

# POWER GENERATION



To: ECS



ENTRY BATTERY A

ENTRY BATTERY B

**WELDOUT FRAME**

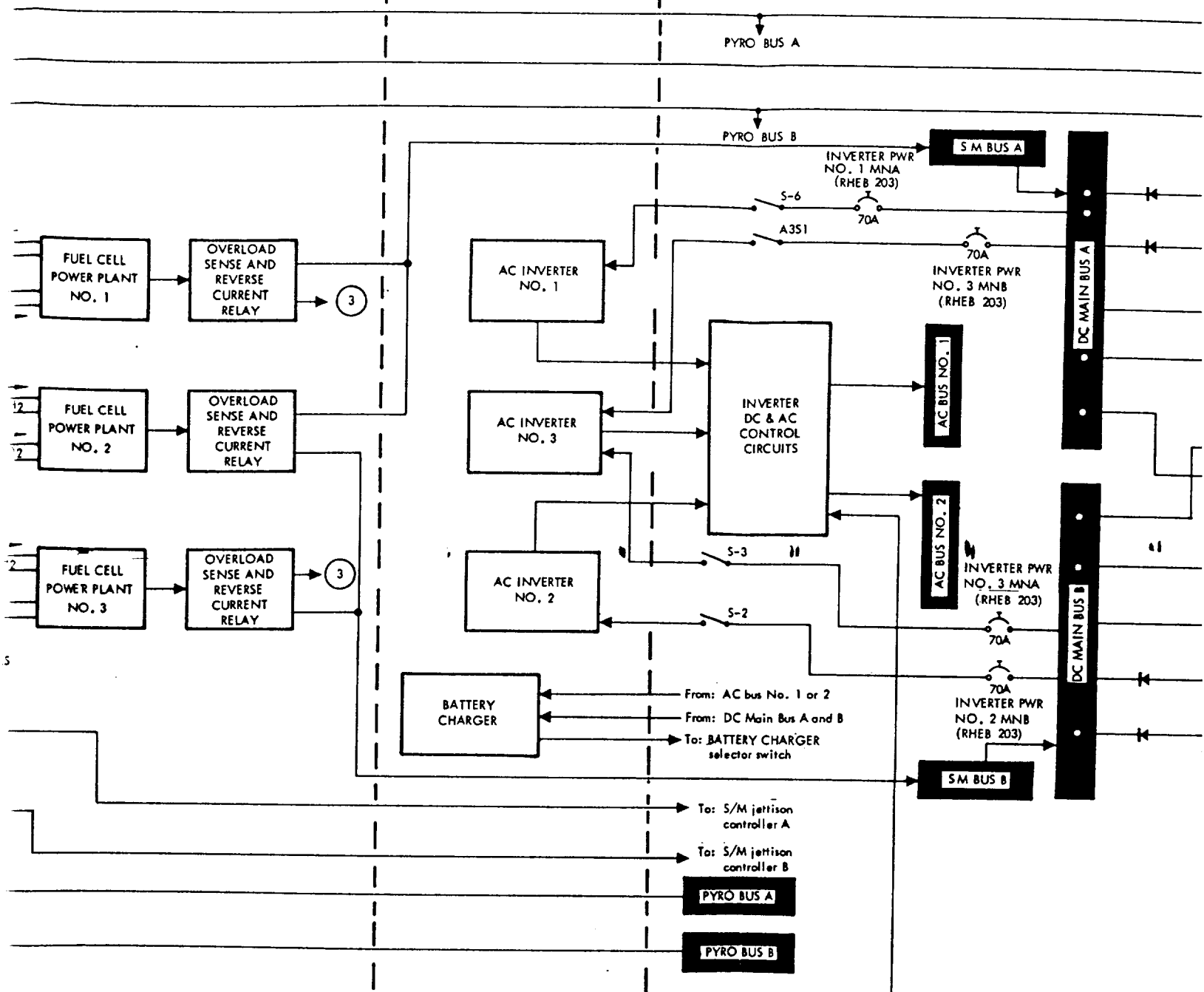




POWER GENERATION

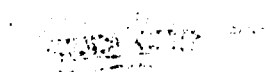
POWER CONVERSION

POWER DISTRIBUTION



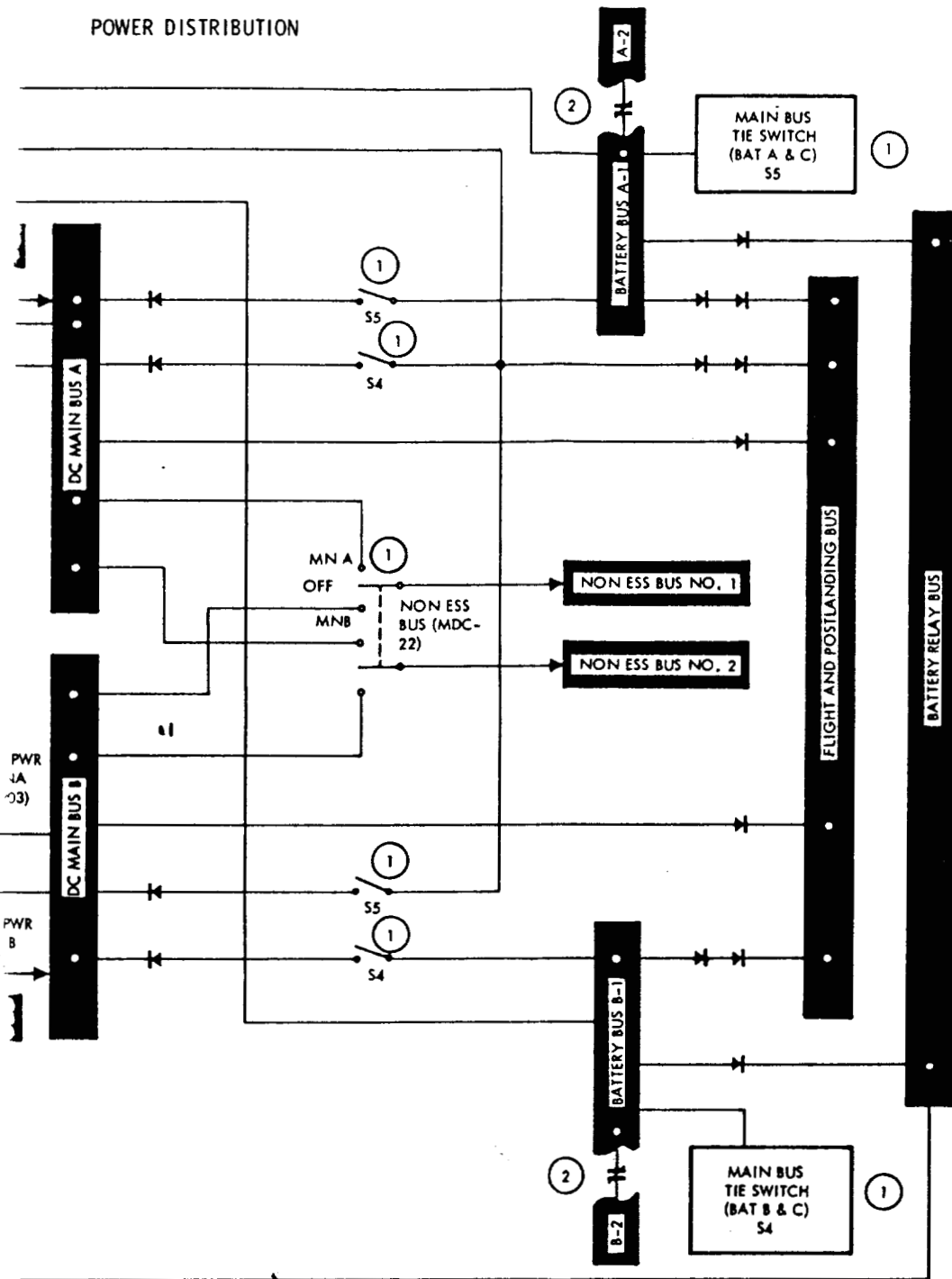
**SOLDOUT FRAME 2**

Miss:



SYSTEMS DATA

POWER DISTRIBUTION



NOTES:

1. Motor switch contacts close when main bus tie switches are set to bat A&C and bat B&C
2. Battery bus contacts remain closed on manned S/C.
3. F/C 1 can be connected to SM Bus B & F/C 3 to SM Bus A.
4. DC Bus control circuit breakers are illustrated in Figure 2.6-11.

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Figure 2.6-1. Electrical Power System Block Diagram

ELECTRICAL POWER SYSTEM

Mission \_\_\_\_\_ Basic Date 12 Nov 1966 Change Date \_\_\_\_\_ Page 2.6-3/2.6-4

**FOLDOUT**



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SYSTEMS DATA

2.6.3 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

2.6.3.1 Cryogenic Storage.

The cryogenic storage system (figure 2.6-2) supplies oxygen and hydrogen reactants to the spacecraft. Hydrogen is supplied to the EPS and oxygen is supplied to both EPS and ECS. The design functions of the two storage systems are identical. The physical data for the cryogenic storage system is given in the following list.

Tank Number	Wt of Usable Cryogenics	Flow Rate at Min dq/dm	Design Storage Press. (Psia)	Min Allowable Operating Pressure	Approx Tank Qtys at Min Heater & Fan Cycling
LO 12	320 lb	0.676 lb/hr	900±35	150 psia	131 to 82 lbs
XTA 0006	320 lb	0.713 lb/hr	900±35	150 psia	131 to 82 lbs
LH 23	28 lb	0.070 lb/hr	245 (+15, -20)	100 psia	14.5 to 7.3 lbs
LH 25	28 lb	0.066 lb/hr	245 (+15, -20)	100 psia	14.5 to 7.3 lbs

The automatic control mode is designed to give a single-phase reactant flow into the F/C and ECS feedlines at design pressures. This control is achieved in effect by controlling the heat transfer within the system. The heat required to maintain constant pressure varies with density. Fill density for oxygen is a little above 70 lbs/ft<sup>3</sup>. As depletion proceeds from 70 lbs/ft<sup>3</sup>, or 100 percent quantity, to approximately 28 lbs/ft<sup>3</sup>, or 40 percent quantity, the cycling of the fans and heaters for repressurization will extend until they cycle least at quantities between 131 and 82 lbs. In the hydrogen system, least amount of heater and fan cycling will occur at quantities between approximately 14.5 and 7.3 lbs. With the system in automatic operation, tank quantities should remain within 15 pounds of each other for oxygen and within one pound difference for hydrogen. The pressure switches activating the heaters and fans are in series. The oxygen switches activate when pressure drops to 865 psia in both tanks. They deactivate when pressure reaches 935 psia in one of the tanks. Keeping the design pressure permits depletion to follow predictable tank densities and respective heat requirements.

When the systems reach the point where the heater and fan cycling is at a minimum, the heat leak of the tank becomes sufficient to maintain design pressures, provided flow is within min dq/dm values as shown in the preceding list. This realm of operation is referred to as being in the minimum dq/dm region. The minimum dq/dm point for oxygen is 23.5 lbs/ft<sup>3</sup> at the nominal operating pressure of 900 psia. The value for hydrogen is 1.87 lbs/ft<sup>3</sup> at 250 psia. The heat required for densities less than the above rises abruptly for both oxygen and hydrogen. The intrinsic flow output of the systems is a maximum at the point where minimum heat is required to maintain pressure. The time-rate of arriving at the minimum dq/dm point is dependent on load demands, tank pressure, and

EPS

ELECTRICAL POWER SYSTEM

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SYSTEMS DATA

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reactant temperature. With design pressures in the tanks, single-phase reactant is available independent of downstream system transfer.

The manual mode of operation simply bypasses the pressure switches. It can be used in case of control failure or when operating with quantity unbalanced depletion. To avoid excessive temperatures, a thermal sensitive interlock device is in series with each heater element in the O<sub>2</sub> and H<sub>2</sub> tanks. These open the heater circuits when internal temperatures reach 80°F and close when temperatures decrease to 70°F. Tank pressures and quantities are monitored on meters located on MDC-13. O<sub>2</sub> tank relief valves initially vent at 983 psig and reseal at 970 psig. H<sub>2</sub> relief valves vent at 273 psig and reseal at 268 psig. The C&W system will alarm when oxygen pressure in either tank exceeds 950 psia, or goes below 800 psia. The hydrogen system alarms the C&W system when pressure in either tank exceeds 270 psia, or goes below 220 psia.

Individual tank pressures, quantities, and reactant temperatures are telemetered to MSFN.

2.6.3.2 Batteries.

A total of seven silver oxide-zinc storage batteries are incorporated in the EPS. Five of these batteries are located in the C/M lower equipment bay, the other two in sector IV of the S/M.

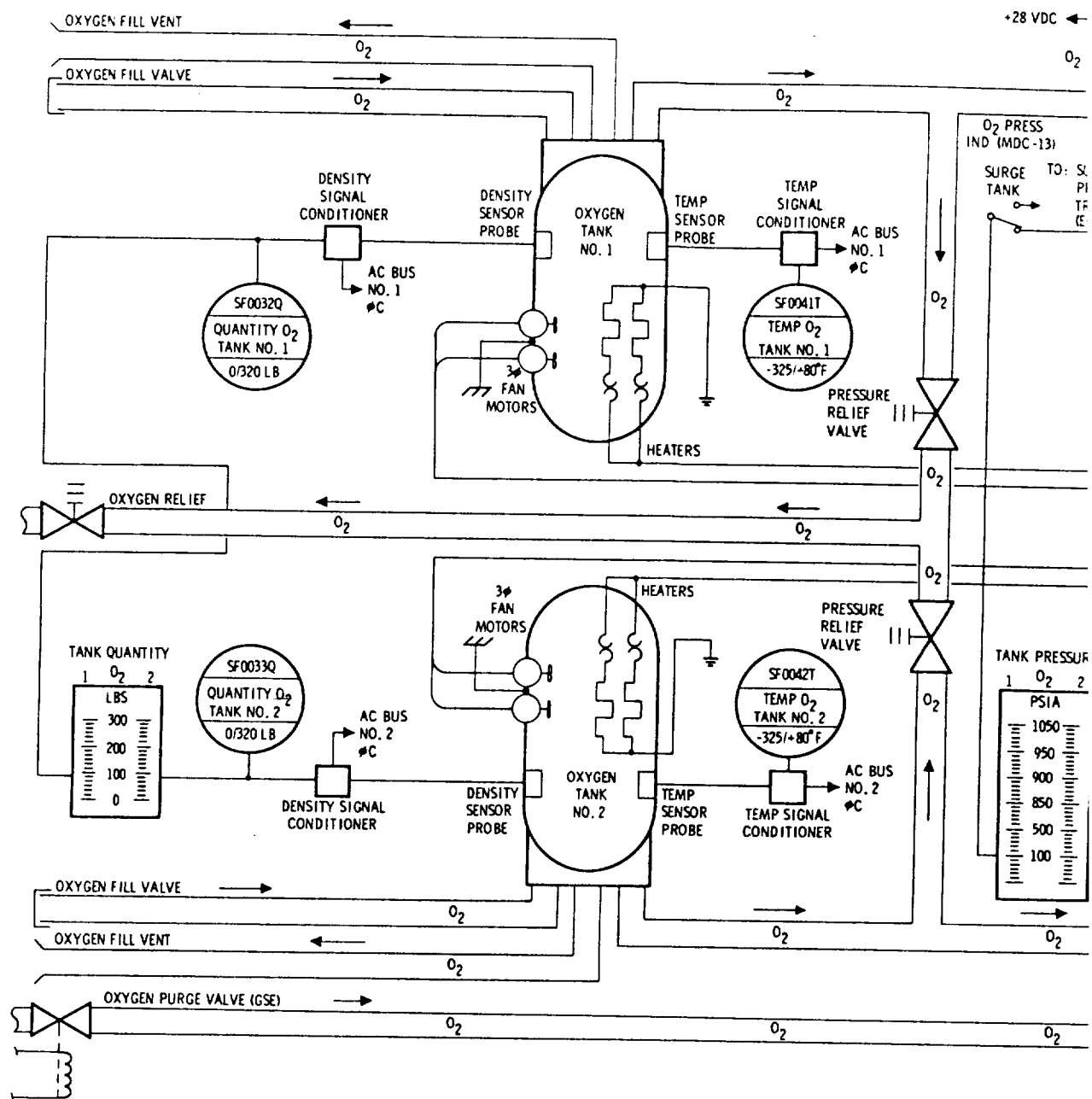
Three entry batteries (A, B, and C) provide the primary source of power after CSM separation and during postlanding operations. Prior to CSM separation, the entry batteries provide a secondary source of power while the fuel cells provide the primary source. The entry batteries are used for the following purposes:

- Provide C/M power after CSM separation
- Supplement fuel cell power during peak load periods (SPS gimbal motor operation)
- Provide power during emergency operations (failure of two fuel cells)
- Provide power for EPS control circuitry (relays, indicators, etc.)
- Provide sequential logic power
- Provide power for recovery aids during postlanding phase
- Batteries A and B can power pyro circuits upon selection.

The entry batteries can be recharged in flight.

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ELECTRICAL POWER SYSTEM



FOLDOUT FRAME /





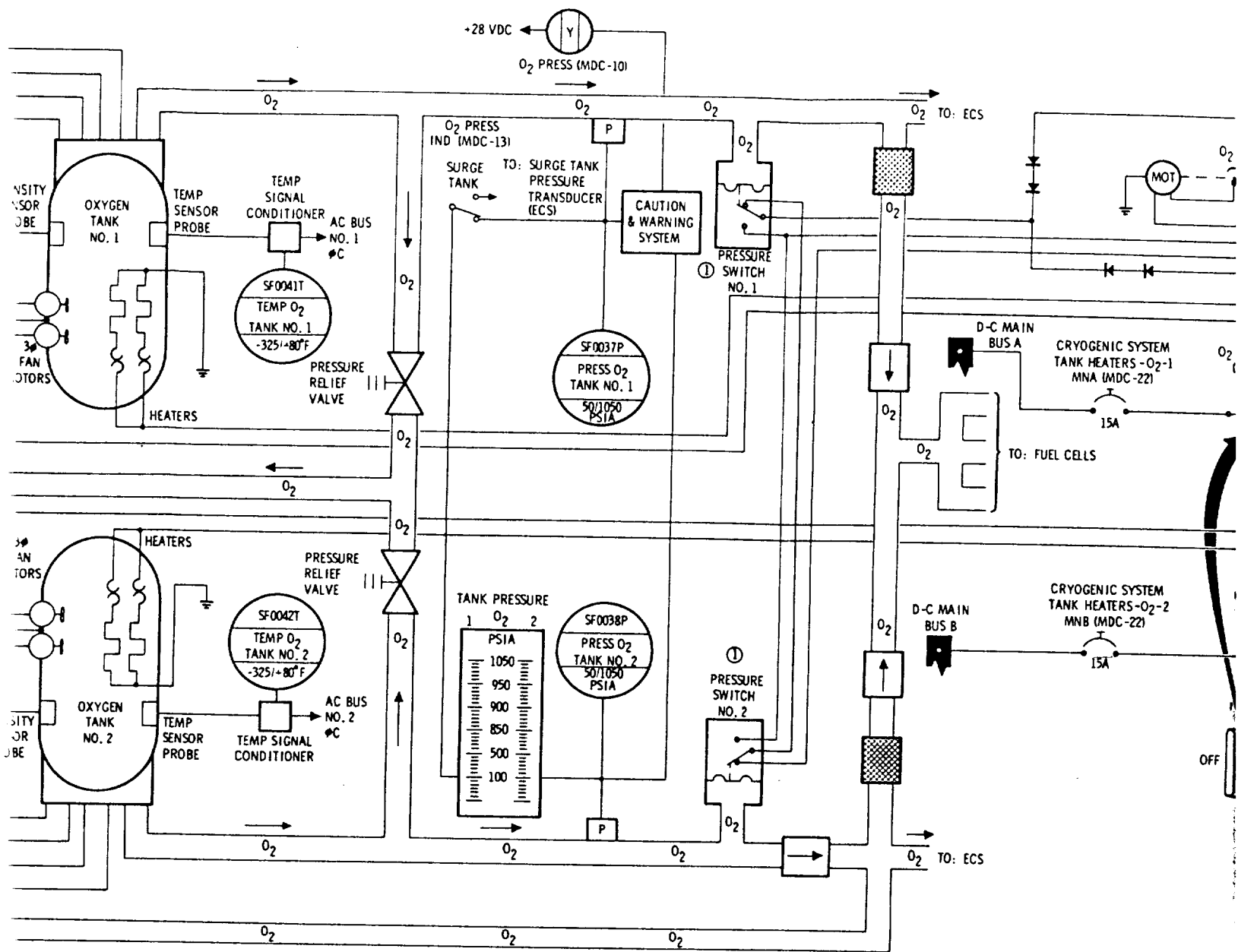


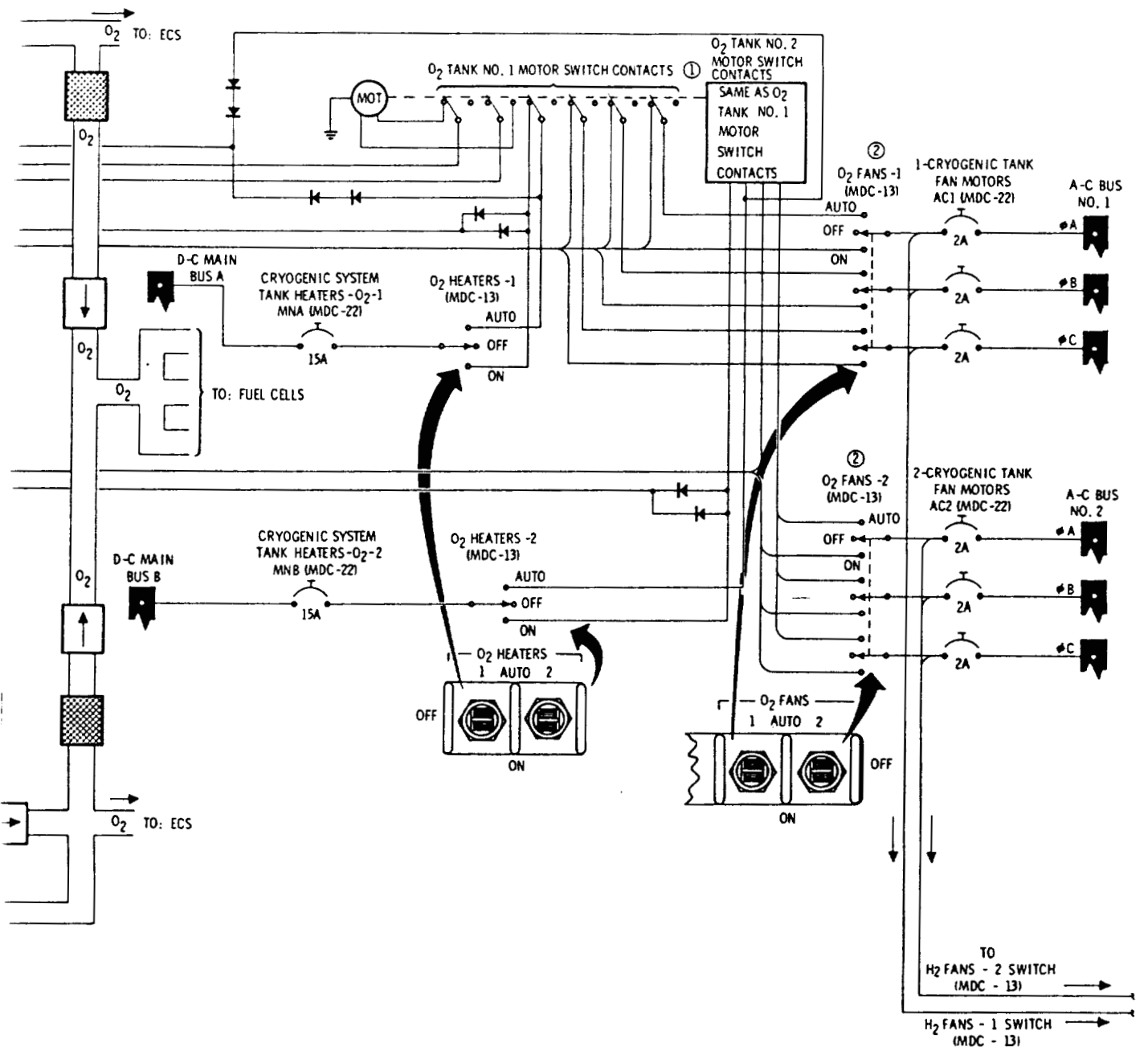
Figure 2.6

FOLDOUT FRAME 2

Mission \_\_\_\_\_ Basic Date \_\_\_\_\_



SYSTEMS DATA



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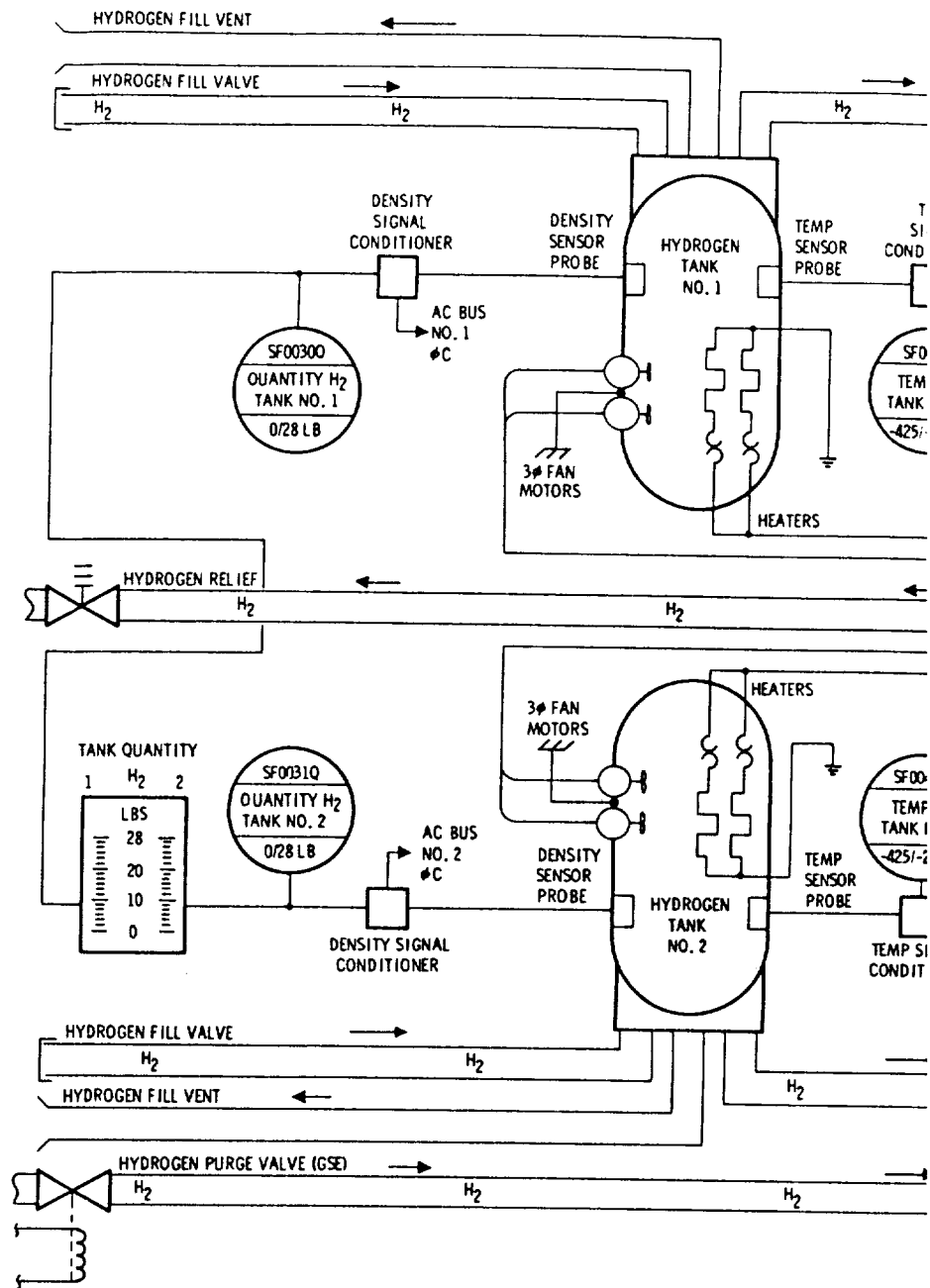
Figure 2.6-2. Cryogenic Storage System (Sheet 1 of 2)

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Mission \_\_\_\_\_ Basic Date 12 Nov 1966 Change Date \_\_\_\_\_ Page 2.6-7/2.6-8

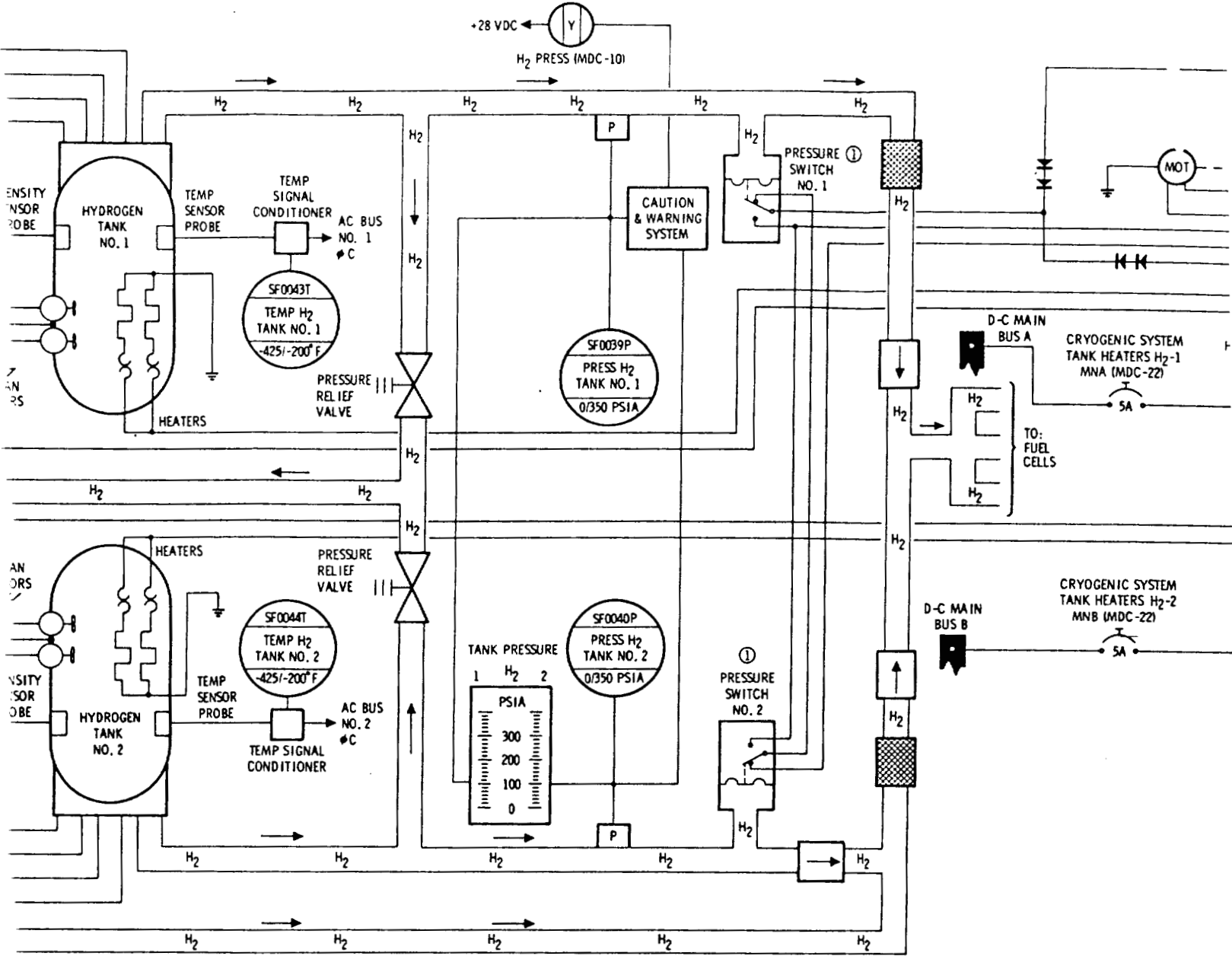
**FOLDOUT FRAME 3**





FROM CB  
 2 - CRYOGENIC TANK FAN MOTORS AC2 (MDC - 22)  
 1 - CRYOGENIC TANK FAN MOTORS AC1 (MDC - 22)





RS AC2 (MDC - 22)  
RS AC1 (MDC - 22)

**FOLDOUT FRAME**

Mission \_\_\_\_\_





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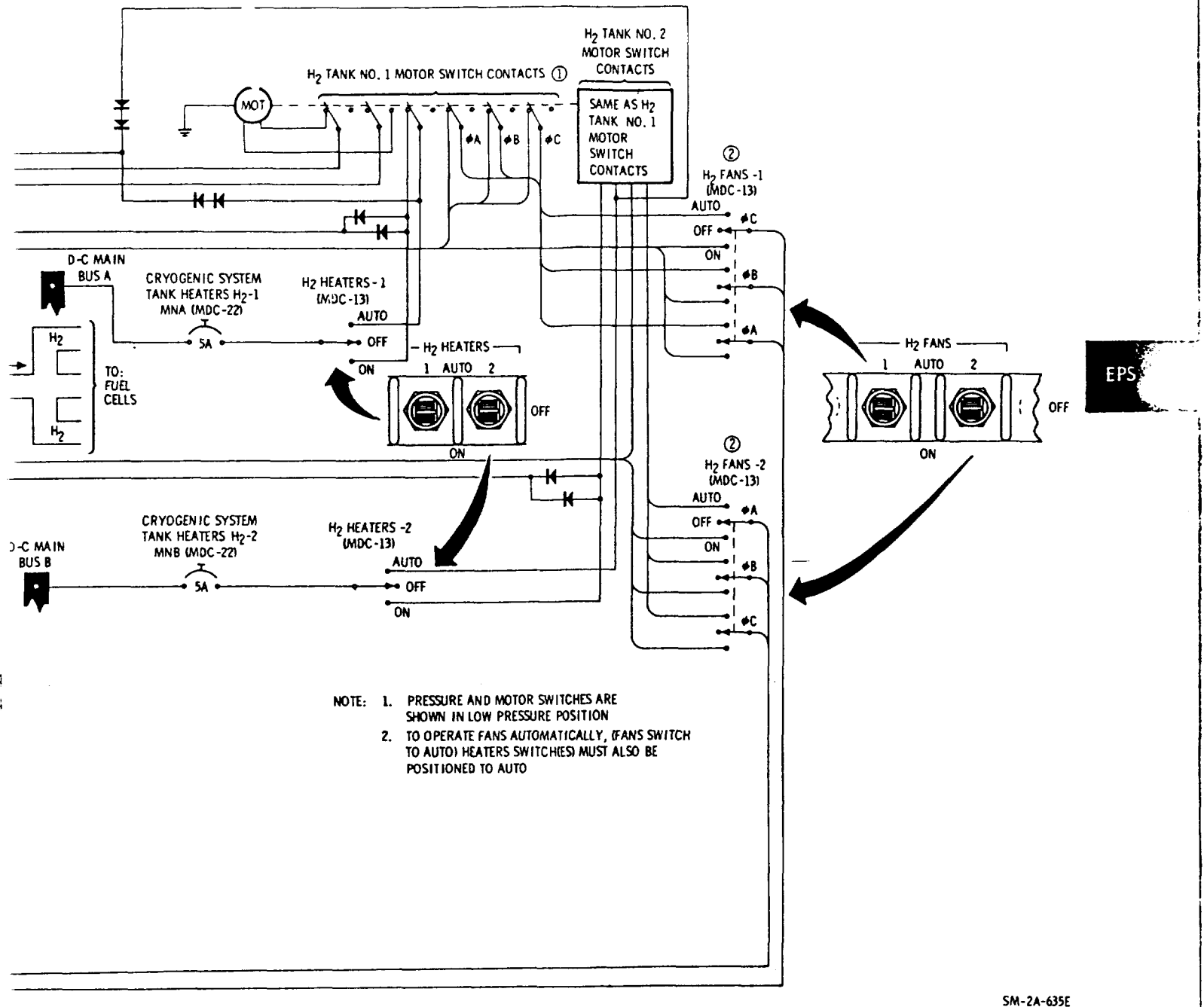


Figure 2.6-2. Cryogenic Storage System (Sheet 2 of 2)

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Each entry battery is mounted within a vented plastic case. The battery cells are individually encased in plastic containers which contain relief valves that open at  $40 \pm 10$  psig, venting pressure and hydrogen gas into the battery case. Each battery case is vented overboard through a manifold leading to a manually operated valve (BATTERY VENT VALVE), which is connected to the ECS dump line. With the valve at its normal position of VENT, the battery cases are vented overboard through the ECS urine/water dump line. In a failure mode, this would prevent hydrogen gas from entering the crew compartment. With the battery vent valve closed, which would be the position after fracture of a battery case, the possibility exists for pressure buildup in the battery manifold due to outgassing of the batteries. The vent valve will be opened at pressures slightly below CM pressure and allow the built-up pressure to vent overboard. Battery manifold pressure can be monitored using the auxiliary DC VOLTS meter, located on panel 200 in the RHFEB, and is telemetered.

The two pyrotechnic batteries supply power to initiate ordnance devices in the S/C. The pyrotechnic batteries are isolated from the rest of the EPS to prevent the high power surges in the pyrotechnic system from affecting the EPS and to ensure source power when required. These batteries shall not be recharged in flight. Entry battery A or B can be used as a redundant source of power for initiating pyro circuits in the respective A or B pyro system, if either pyro battery fails.

EPS

The two S/M jettison controller batteries, located in the S/M, supply power to two jettison sequencers to sustain the S/M RCS retrofire, as well as firing the S/M positive roll RCS engines two seconds after CSM separation. These batteries are isolated from the rest of the EPS and cannot be recharged or monitored in flight.

Performance characteristics of each S/C battery are as follows:

Battery	Capacity per Battery	No. of Cells per Battery	Open Circuit Voltage (Max.)	Nominal Voltage	Minimum Voltage	Ambient Battery Temperature
Entry A, B, and C (3)	40-amp-hrs (25 ampere rate)	20	37.8 vdc (37.2 vdc in flight)	29.0 vdc (35 amps load)	27.0 vdc (35 amps load)	50° to 110°F
Pyro A and B (2)	75 amps for 36 seconds	20	37.8 vdc (37.2 vdc in flight)	23.0 vdc (75 amps load)	20.0 vdc (75 amps load) (35.0 vdc open circuit)	60° to 110°F

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Battery	Capacity per Battery	No. of Cells per Battery	Open Circuit Voltage (Max.)	Nominal Voltage	Minimum Voltage	Ambient Battery Temperature
S/M jettison controller A and B (2)	75 amps for 36 seconds	20	37.8 vdc (not measur- able in S/C or by telemetry)	23.0 vdc (75 amps load)	20.0 vdc (75 amps load)	60° to 110° F

NOTE Pyro battery load voltage is not measurable due to the extremely short time they power pyro loads.

2.6.3.3 Fuel Cell Power Plants.

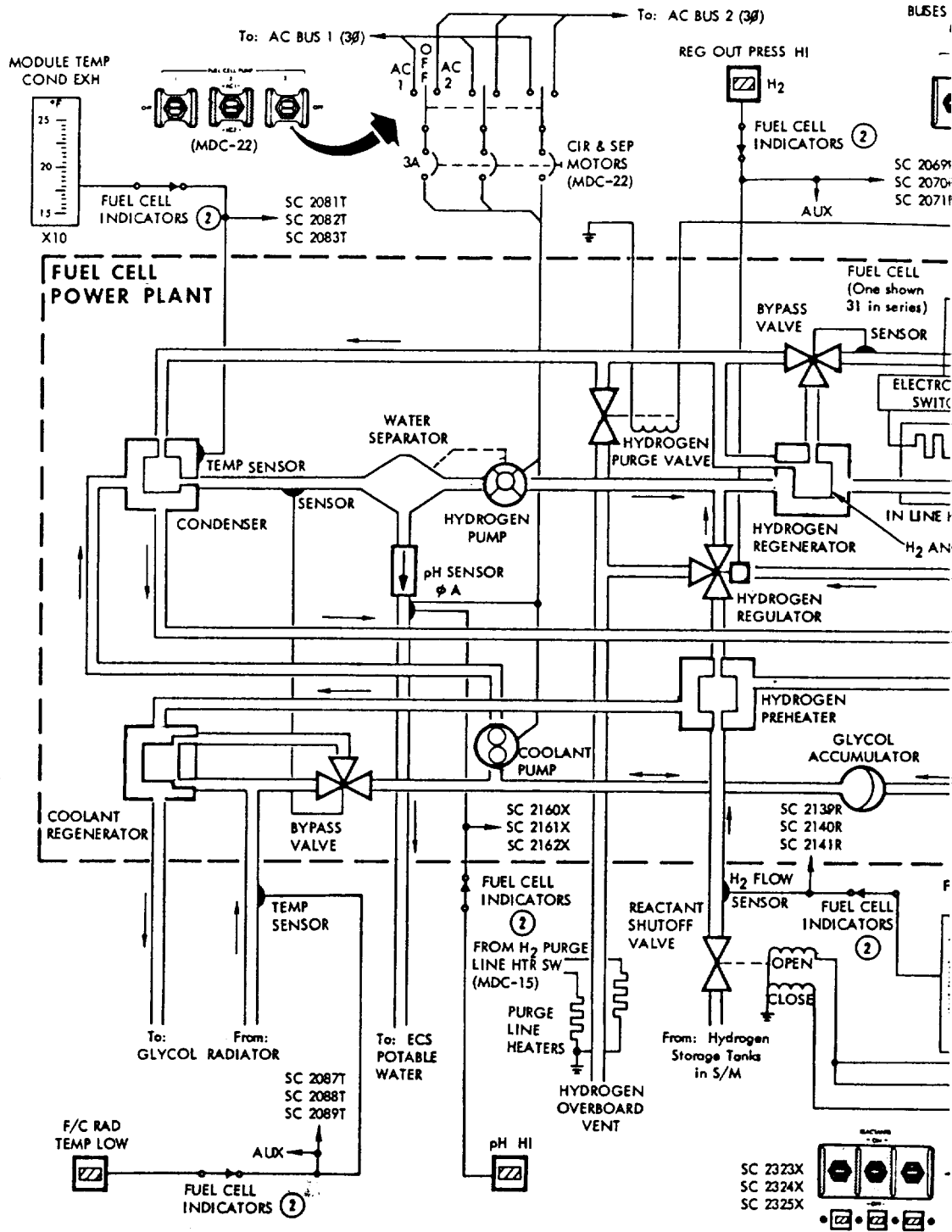
Each fuel cell power plant consists of 31 single cells, connected in series, and an accessory section. Each single cell generates approximately 1 volt. The accessory section consists of a nitrogen pressurization system, an oxygen feed, a hydrogen feed, a primary (hydrogen) loop, and a secondary (glycol) loop (figure 2.6-3). The primary and secondary loops control the temperature within the fuel cell power plant. The primary loop also extracts potable water from the power plant for use by the crew. The secondary loop radiates heat from the power plant into space through radiators located on the exterior of the S/M.

The nitrogen system establishes a reference pressure in the fuel cell. There is approximately 0.44 lbs of N<sub>2</sub> contained in the nitrogen tank under a pressure of 1500 psia. The nitrogen regulator reduces this pressure to 52 psia, which is used to pressurize the glycol accumulator, the electrolyte (KOH) in the cells, and as a reference pressure for the oxygen and hydrogen regulators.

Oxygen, stored in a cryogenic state at a pressure of 900±35 psia, is supplied to the fuel cell power plants. Due to the low-flow rate, the oxygen absorbs heat while flowing through the lines, absorbs additional heat in the preheater, flows to the oxygen regulator, and reaches the fuel cell power plants in a gaseous form at temperatures above +100°F. The regulator is designed to maintain a pressure differential of 10.5 psia above the nitrogen pressure, supplying the oxygen to the fuel cell at a nominal 62.5 psia. The oxygen in the system is approximately 99.99 percent pure. Over a period of time, the impurities accumulate in the reactant compartment and decrease fuel cell efficiency. This is noted by a drop in fuel cell performance. To eliminate the impurities, the fuel cell is purged. Normally a fuel cell will be purged every 24 hours; however, the actual purge cycle will be determined by the predicted mission power profile and the purity of the reactant as it is calculated to be after

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**WOLDOUT FRAME**

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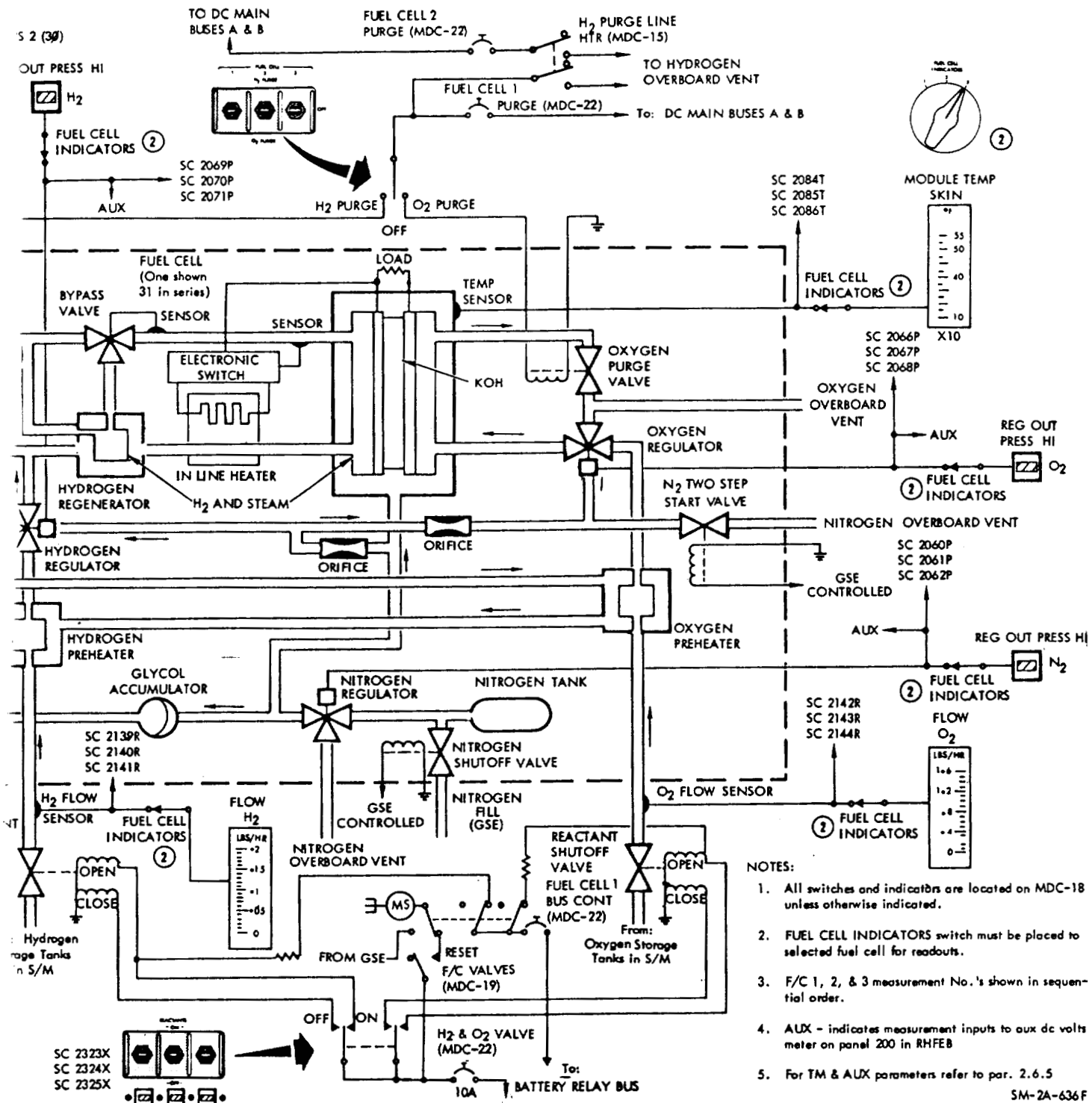


Figure 2.6-3. Fuel Cell Power Plant Flow Diagram

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completion of S/C cryogenic tank fill. Time required for oxygen purge is 2 minutes for each power plant. Activating the O<sub>2</sub> purge valve allows an additional flow of up to 0.6 lb per hr. An emergency purge can be performed if steady state current output of a power plant decreases by approximately 3 amps. Power plant parameters (primarily voltage, current, and skin temperature) must be considered to determine if an emergency purge is required.

Hydrogen, stored in a cryogenic state at a pressure of 245 (+15, -20) psia and regulated down to a pressure of 60.5 psia, flows into the hydrogen regenerator loop, passing through an in-line heater and into the fuel cell. The in-line heater is an automatic device which aids the fuel cell power plant in sustaining operating temperature at low-power operating levels. The hydrogen, or primary regenerator loop, is used for fuel cell thermal control and permits water removal from the fuel cell. The heat generated by the reaction is transferred to the saturated H<sub>2</sub> fluid. The hot, saturated hydrogen is drawn into the hydrogen exhaust line by the H<sub>2</sub> pump. A sensor in this line provides an input to an electronic switch which controls activation of the H<sub>2</sub> in-line heater. Activation of this heater is accomplished automatically at a hydrogen exhaust temperature of 385±5°F, supplying additional heat to hydrogen gas flowing to the fuel cell power plant. The in-line heater is automatically deactivated at a temperature of 390±5°F. After passing the in-line heater sensor, the saturated hydrogen flows to a sensor-controlled bypass valve. This valve controls the amount of exhaust gas flowing through the H<sub>2</sub> regenerator. The sensor closes the bypass valve at 425°F, allowing all exhaust gas to flow through the regenerator. This heats the returning hydrogen and sustains operating temperature of the fuel cell. With the bypass valve in a full regenerative position (temperatures 425° or lower), if fuel cell power plant temperature continues to decrease, the in-line heater will be activated to supply additional heat. If power plant temperature is above 425°F, the sensor causes the bypass valve to open proportionately (fully open at 495°F) allowing exhaust gas to flow directly to the condenser. A transfer of heat from the hydrogen and steam to the glycol takes place in the condenser. The temperature of the hydrogen and steam is lowered to between 155° and 175°F, thus liquifying some of the water vapor. A sensor in the condenser exhaust, controls a glycol regenerator bypass valve in the glycol radiator return line which regulates the temperature of the glycol. This, in turn, helps control fuel cell temperature and maintains the temperature of the condenser exhaust within the desired range of 155° to 175°F. The liquid water and hydrogen then flows through a centrifugal water separator pump which extracts the water and delivers it to the ECS potable water storage tank in the C/M. The amount of water produced by each fuel cell is in direct relation to the reactants consumed which is related to power output. (See figure 2.6-4.)

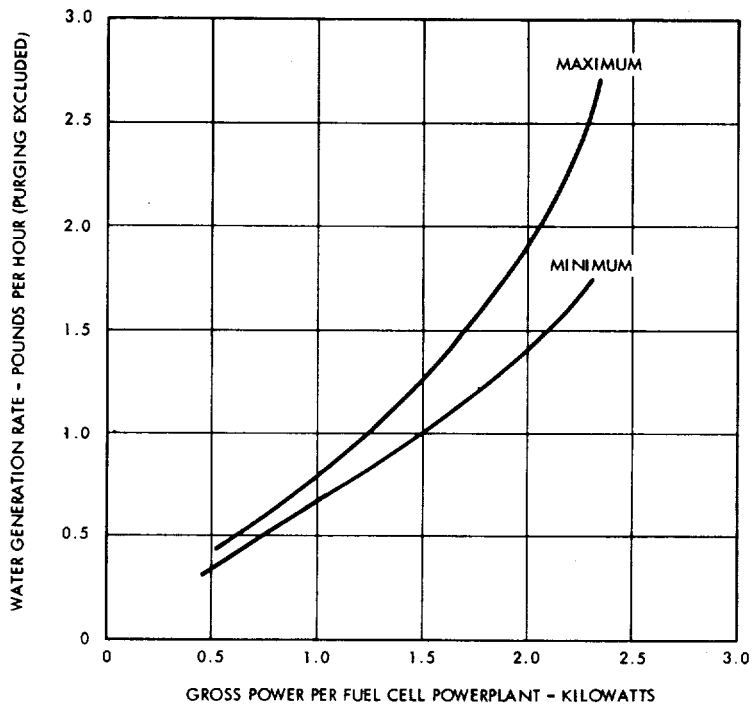
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Figure 2.6-4. Water Production Rate vs Power Output

The hydrogen pump circulates the remaining slightly moist fluid through the regenerator and back to the fuel cell. In order to maintain the desired ratio of water to KOH in the fuel cell, the condenser exhaust temperature is regulated at a level so that some moisture is left in the returning hydrogen as it flows back into the cell. The hydrogen in the cryogenic system is approximately 99.94 percent pure. H<sub>2</sub> purge valve activation allows an additional flow of up to 0.75 lbs per hour, and will normally be performed for a period of 80 seconds per power plant every 24 hours. The actual H<sub>2</sub> purge cycle will also depend on the predicted power profile and reactant purity as calculated after cryogenic tank fill. The performance degradation participation by the H<sub>2</sub> electrode is negligible and cannot be seen with on-board instrumentation (with normal degradation). If degradation is suspected to remain after an emergency O<sub>2</sub> purge, an H<sub>2</sub> purge may be warranted. There is some indication that periodic H<sub>2</sub> purging may be eliminated altogether, thereby only performing the degradation purge whenever it may be required. Thirty minutes prior to H<sub>2</sub> purging, the H<sub>2</sub> PURGE LINE HTR switch (MDC-15) is placed in the up position to energize the H<sub>2</sub> fuel cell vent line heater and preclude any freezing of the moist exhaust gas in the vent line.

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The secondary loop contains a 62.5 to 37.5 mixture of ethylene glycol and water, respectively. This loop serves to preheat the reactants and to transport waste heat to the space radiators. An accumulator, pressurized by the nitrogen, pressurizes the glycol loop and also acts as a buffer for the expansion and contraction of the coolant as it varies in temperature. Glycol flow through the regenerator is controlled by a bypass valve which operates in conjunction with the condenser exhaust sensor. When the condenser exhaust is at 155°F, the glycol is routed through the regenerator to increase glycol temperature and effect minimum heat transfer in the condenser. The glycol bypass valve is completely open at a condenser exhaust temperature of 175°F, routing the glycol through the pump to the condenser and on to the oxygen and hydrogen preheaters. Since the glycol temperature is lower, a maximum transfer of heat in the condenser lowers the condenser exhaust temperature. The condenser exhaust temperature sensor regulates coolant temperature which affects the amount of water removed from the power plant. The 155° to 175°F operating range will best maintain the desired ratio of water to KOH in the fuel cell.

A 400-cps 3-phase a-c gear pump maintains glycol flow at the rate of 35 to 80 lbs per hour, raising the pressure 6 psi. After the oxygen and hydrogen preheaters, the glycol is routed through the glycol regenerator and to the space radiators, where heat is radiated into the space environment.

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Each fuel cell contains electrolyte (KOH) which consists by weight of 83 percent potassium hydroxide and 17 percent water on initial fill, and has a critical temperature of 300°F (figure 2.6-5). The electrolyte remains a solid to an approximate temperature of 220°F; with a temperature increase to 300°F, the electrolyte becomes a liquid and the fuel cell electrochemical reaction becomes effective. Bringing the fuel cell to critical temperature is accomplished using GSE, and cannot be performed from S/C power sources. Placing a load on the power plant will maintain it above this critical temperature.

2.6.3.4

Inverters.

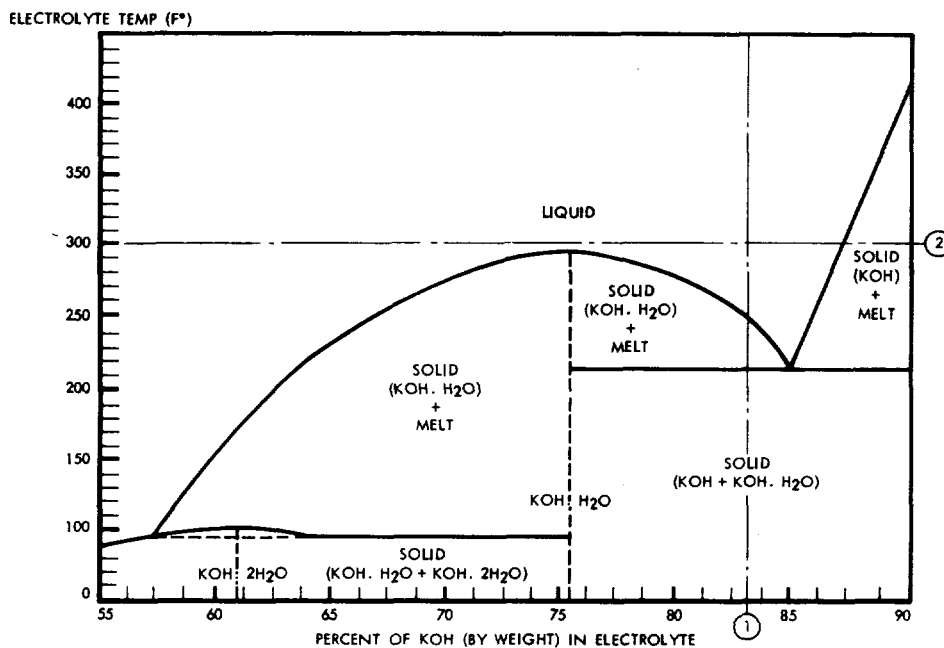
Each inverter (figure 2.6-6) is composed of a clock oscillator, an eight-stage digital countdown section, a d-c line filter, two silicon-controlled rectifiers, a magnetic amplifier, a buck-boost amplifier, a demodulator, two d-c filters, an eight-stage power inversion section, a harmonic neutralization transformer, an a-c output filter, current sensing transformers, a Zener diode reference bridge, a low-voltage control, and an overcurrent trip circuit. The inverter normally uses a 6.4-kc square wave synchronizing signal from the central timing equipment (CTE) which maintains inverter output at 400±2 cps. If this external signal is completely lost, the oscillator within the inverter will provide pulses that will maintain inverter output within ±7 cps. The internal

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NOTES: 1. Percent (83) of KOH in electrolyte at initial fill.  
2. Critical temperature (300°F) of electrolyte at which electrochemical reaction begins, on initial start-up of fuel cell.

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Figure 2.6-5. KOH H<sub>2</sub>O Phase Diagram

oscillator is normally synchronized by the external pulse which is provided through the phase synchronizing unit. The phase synchronizer will provide these pulses to the inverter after a maximum of two seconds. The following paragraphs describe the function of the various stages of the inverter.

The 6.4-kc negative square wave provided by the central timing equipment is applied through the phase synchronizer and the oscillator to the eight-stage digital countdown section. The oscillator has two divider circuits which provide a 1600-pps signal to the magnetic amplifier and two silicon-controlled rectifiers.

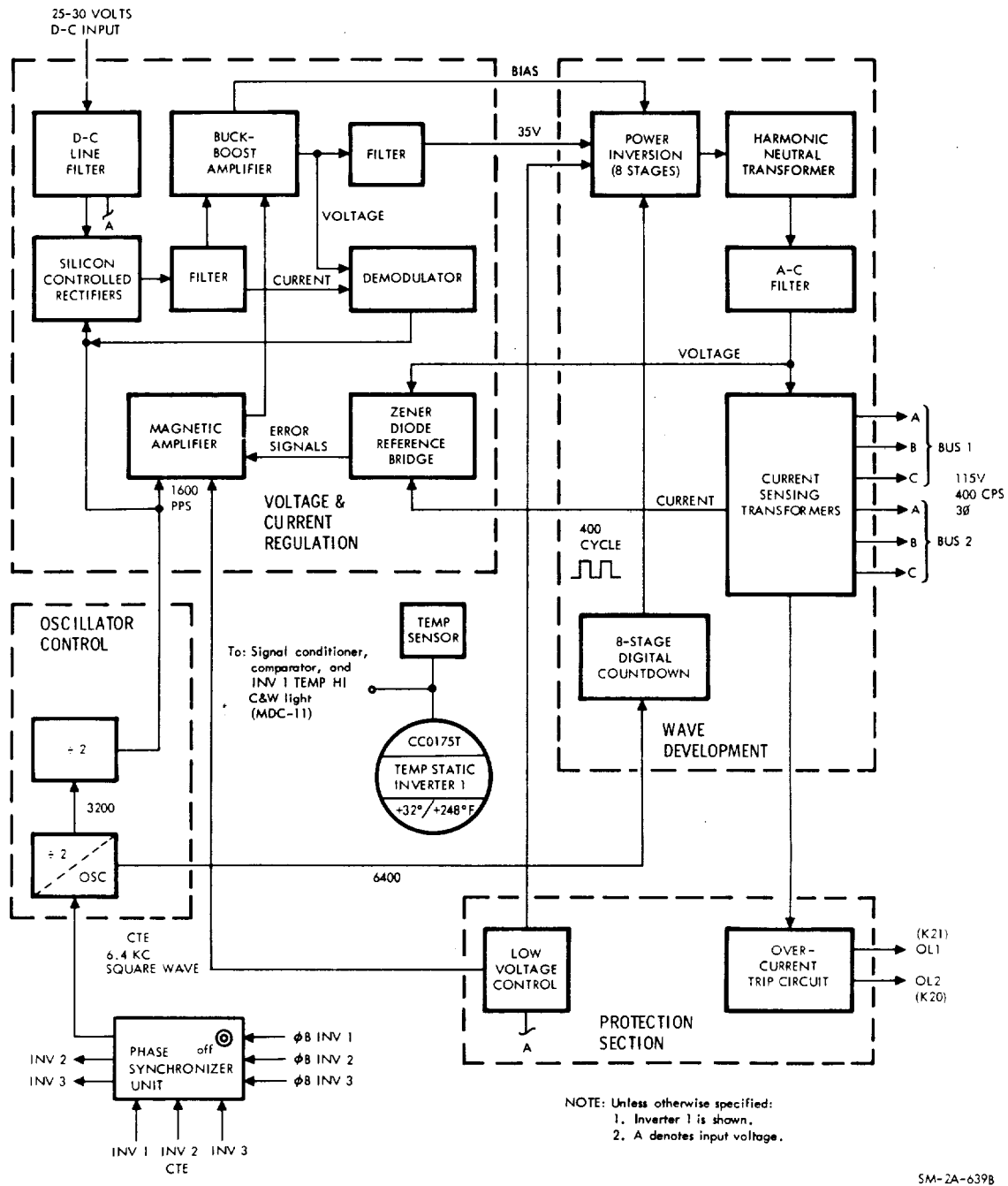
The eight-stage digital countdown section uses the 6.4-kc square wave signal to produce a series of eight 400-cycle square waves, each mutually displaced one pulse time from the preceding and following wave. Once pulse time is 156 microseconds and represents 22.5 electrical degrees. This series of square waves is applied to the eight-stage power inversion section.

The eight-stage power inversion section, using a controlled voltage from the buck-boost amplifier, amplifies the series of 400-cycle square waves produced by the eight-stage digital countdown section. The amplified square waves, still mutually displaced 22.5 electrical degrees, are applied to the harmonic neutralization transformer, which is described in a subsequent paragraph.

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Figure 2.6-6. Inverter Block Diagram

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D-C power to the inverter is supplied from the main d-c buses through the d-c line filter. This filter reduces the high frequency ripple in the input, and the 25 to 30 vdc is applied to the silicon-controller rectifiers and buck-boost amplifier.

The silicon-controlled rectifiers, using the filtered d-c power and the 1600-pps signal from the clock oscillator, produce a d-c square wave with an on-time of greater than 90 degrees from each rectifier. This is filtered and supplied to the buck-boost amplifier where it is coupled with the amplified 1600-pps output of the magnetic amplifier to develop a filtered 35 volts dc which is used for amplification in the power inversion stages.

The buck-boost amplifier, using the 1600-pps signal from the magnetic amplifier, the filtered d-c power from the main duc buses, and an error signal feedback from the Zener diode reference bridge, provides a variable bias voltage to the eight-stage power inversion section. The amplitude of this voltage is controlled by the amplitude and phase of the feedback signal from the Zener diode reference bridge. This bias signal is varied by the error signal to regulate inverter voltage and current output.

The demodulator compensates for any low-frequency ripple in the d-c input to the inverter. The high-frequency ripple is attenuated by the filters. The demodulator senses the 35-volt d-c output of the buck-boost amplifier and the current input to the buck-boost amplifier. It compensates for ripple in the 10- to 1000-cps range. An input voltage drop or increase will be reflected in a drop or increase in the 35-volt d-c output of the buck-boost amplifier as well as a drop or increase in current input to the buck-boost amplifier. A sensed decrease in the buck-boost amplifier voltage output would be compensated for a demodulator output, transformer coupled, to the silicon-controlled rectifiers, causing them to conduct for a longer time, thus increasing their filtered output. A sensed increase in buck-boost amplifier voltage output, caused by an increase in the d-c input to the inverter, would cause the demodulator to produce a signal causing the silicon-controlled rectifiers to conduct for shorter periods, producing a lower filtered output to the buck-boost amplifier. In this fashion, the 35-volt d-c input to the power inversion section is maintained at a relatively constant level.

The low-voltage control samples the input voltage to the inverter and can terminate inverter operation. Since the buck-boost amplifier provides a boost action during a decrease in input voltage to the inverter, in an attempt to maintain a constant 35 volts dc to the power inversion section, the high boost required during a low-voltage input would tend to overheat the buck-boost amplifier. As a precautionary measure, the low-voltage control will terminate inverter operation by disconnecting operating voltage to the magnetic amplifier and a power inversion stage when input voltage decreases to between 16 and 19 volts dc.

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The harmonic neutralization section, using the 400-cycle, square-wave output of the eight-stage power inversion section, transforms it into a 3-phase 400-cycle 115-volt sine wave signal. The manner in which these transformers are wound produces flux cancellation which eliminates all harmonics up to and including the fifteenth of the fundamental frequency. The 22.5 electrical degree displacement of the square wave provides a means of electrically rotating the square wave excited primary windings around the 3-phase, wye-connected, secondary windings, thus producing the 3-phase 400-cycle sine wave output. This 115-volt signal is then applied to the a-c output filter.

The a-c output filter eliminates the remaining higher harmonics. Since the lower harmonics were eliminated by the harmonic neutralization section, the size and weight of this output filter was reduced. Circuitry in this filter also produces a rectified signal which is applied to the Zener diode reference bridge. The amplitude of this signal is a function of the amplitude of a-c output voltage. After filtering, the 3-phase 115-volt a-c 400-cycle sine wave is applied to the a-c buses through current-sensing transformers.

The current-sensing transformer section produces a rectified signal, the amplitude of which is in direct function of inverter output current magnitude. This d-c signal is applied to the Zener diode reference bridge to regulate inverter current output. It is also applied to an overcurrent trip circuit.

The Zener diode reference bridge receives a rectified d-c signal, representing voltage output, from the circuitry in the a-c output filter. A variance in voltage output unbalances the bridge providing an error signal of proper polarity and magnitude to the buck-boost amplifier via the magnetic amplifier. When inverter current output reaches 200 to 250 percent of rated current, the rectified signal applied to the bridge from the current sensing transformers is of sufficient magnitude to provide an error signal and cause the buck-boost amplifier to operate in the same manner as during an overvoltage condition. The bias output of the buck-boost amplifier, being controlled by the error signal, will be varied to correct for any variation in inverter voltage or current output. When inverter current output reaches 250 percent of rated current, the overcurrent trip circuit is activated.

The overcurrent trip circuit monitors a rectified d-c signal representing current output. When total inverter current output exceeds 250 percent of rated current, this circuit will effect an inverter disconnect in  $15 \pm 5$  seconds. If current output of any single phase exceeds 300 percent of rated current, this circuit will effect an inverter disconnect in  $5 \pm 1$  second.

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A phase synchronizer unit (PSU), located in the RHEB (panel 208), establishes inverter outputs so they are in phase when using a separate inverter on each of the two a-c buses. The two inverter configuration is prevalent during delta V's as a safety precaution in case of a single failure in thrust vector control.

The use of two inverters during delta V's retains redundancy in the stabilization and control subsystem, since power through a-c bus 1 is used for automatic thrust vector control and power through a-c bus 2 is used for manual thrust vector control.

Central timing equipment (CTE) trigger pulses, used for inverter operation, are supplied to the inverters through the PSU. The PSU samples  $\phi B$  from each inverter output, and when an in-phase relationship is established, supplies the 6400-cps CTE trigger pulse to the inverters being used. The  $\phi B$  input also supplies power for PSU circuitry.

The in-phase relationship is acquired by initially providing out-of-phase trigger pulses (6080 to 6400 cps) until the two inverters are synchronized, at which time the CTE signal is coupled to the inverters. Phase lock, with a maximum displacement of  $\pm 10$  degrees, is acquired in a maximum of two seconds.

The synchronizer provides this function for any combination of pairs of the three available inverters. A two-position toggle switch on the PSU, when positioned to OFF, allows for direct input of CTE signals to the inverters in the event of failure of the synchronizer unit. However, in this situation, the in-phase relationship would not be realized.

A temperature sensor with a range of  $+32^{\circ}$  to  $+248^{\circ}\text{F}$  is installed in each inverter to provide MSFN the capability of monitoring inverter temperature. It also provides an input to the C&WS which will illuminate a light at an inverter overtemperature of  $226^{\circ}\text{F}$ .

2.6.3.5 Battery Charger.

A constant voltage, solid-state battery charger (figure 2.6-7), located in the C/M lower equipment bay, is incorporated into the EPS. The battery charger selector switch (MDC-18) controls power input to the charger, as well as connecting the charger output to the selected battery (figure 2.6-11). When the BATTERY CHARGER selector switch is positioned to entry battery A, B, or C, a relay (K4) is activated, completing circuits from a-c and d-c power sources to the battery charger. Also, the battery charger output is connected to the selected battery to be charged through the MAIN BUS TIE switches (MDC-22). Positioning the MAIN BUS TIE switch (A&C or B&C) to OFF, for the selected batteries, will disconnect main bus loads from the batteries and also complete the circuit from the charger to the battery. Only one battery can be charged at a time.

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The battery charger uses 25 to 30 volts dc from the main d-c buses and 115 volts 400-cps, 3-phase ac from either of the a-c buses. All three phases of ac are used to boost the 25 to 30-volt d-c input to produce 40 volts dc for charging. In addition, phase A of the ac is used to supply power for the rest of the charger circuitry. The logic network in the charger, which consists of a two-stage differential amplifier (comparator), a two-stage Schmitt trigger, a current sensing resistor, and a voltage amplifier will set up the initial condition for operation. The first stage of the comparator is in the on mode, with the second stage in the off mode, placing the Schmitt trigger first stage in the on mode with the second stage off. This condition provides maximum base drive to the current amplifier which turns the switching transistor to the on mode. With the switching transistor on, current flows from the transformer rectifier through the switching transistor, current sensing resistor, and switch

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choke to the battery being charged. As current flow increases, the voltage drop across the sensing resistor increases. The voltage across the sensing resistor builds to a level which turns the first stage of the comparator to the off mode and the second stage to the on mode. This condition turns off the voltage amplifier which reverses the operation of the Schmitt trigger to first stage off and second stage on. This places the current amplifier off, which turns off the switching transistor. The switching transistor in the off mode will stop current flow from the power source, causing the field in the choke to continue collapsing and discharging into the battery through the switching diode and the current sensing resistor. As the EMF in the choke decreases, the current through the sensing resistor decreases, reducing the voltage drop across the resistor. At some point, the decrease in voltage drop across the sensing resistor, reverses the operation of the comparator circuit, setting up the initial condition and completing one cycle of operation. The output load current, due to the action of the choke, remains relatively constant except for the small variation through the sensing resistor. This variation is required to switch the switching transistor and Schmitt trigger through the action of the comparator.

Battery charger output is regulated by the sensing resistor until the battery voltage reaches approximately 36 volts. At this time, the voltage control network is activated and, in conjunction with the sensing resistor, provides a signal for cycling the battery charger. As the battery voltage increases, the internal impedance of the battery increases, decreasing current flow from the charger. At 39 volts, the battery is fully charged and current flow becomes negligible. (See figure 2.6-8.) Battery charger disconnect will be effected at a current output of approximately 0.6 amps.

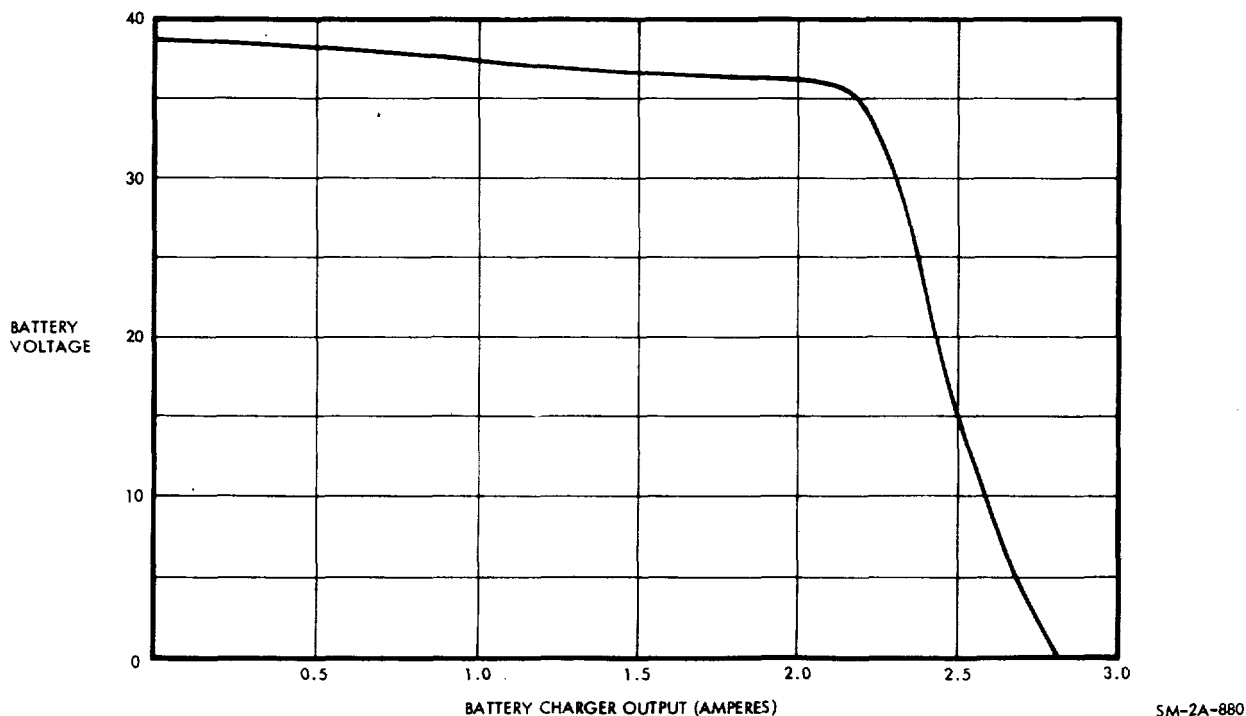


Figure 2.6-8. Battery Charging Rate Chart

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Battery input will be monitored by MSFN through the normal battery telemetry measurements.

2.6.3.6      Power Distribution.

D-C and a-c power distribution to components of the EPS is provided by two redundant buses in each system. A single-point ground on the spacecraft structure is used to eliminate ground loop effects. Sensing and control circuits are provided for monitoring and protection of each bus system.

Distribution of d-c power (figure 2.6-9) is accomplished with a two-wire system and a series of interconnected buses, individual switches, circuit breakers, and isolation diodes. The buses consist of the following:

- Two redundant main d-c buses (A and B) powered by the three fuel cells and/or entry batteries A, B, and C.
- Two battery buses (A and B) each powered by its respective entry battery A and B.
- Flight and postlanding bus, powered through the main d-c buses, and/or the three entry batteries, A, B, and C.
- Two nonessential buses, powered through either d-c main bus A or B.
- Battery relay bus, powered by entry batteries A and B through individual battery buses.
- Pyro buses, which are isolated from the main electrical power system when powered by the pyro batteries. A capability is provided to connect entry battery A or B to the respective A or B pyro system in case of loss of a pyro battery.
- S/M jettison controllers, powered by S/M jettison controller batteries, which are completely isolated from the main electrical power system.

EPS

Power from the fuel cell power plants is connected to the main d-c buses through six motor switches (part of overload/reverse current circuits in the S/M which are controlled by switches in the C/M located on MDC-18. Fuel cell power can be connected to either or both of the main d-c buses. Six event indicators show when fuel cell output is connected. When an overload condition occurs, the overload-reverse current sensing circuits automatically disconnect the fuel cell power plants from the overloaded bus and provide visual displays for isolation of the trouble. A reverse current condition will disconnect the malfunctioning power plant from the d-c system. D-C undervoltage sensing circuits (figure 2.6-10) are also provided to indicate bus low voltage conditions. If voltage drops

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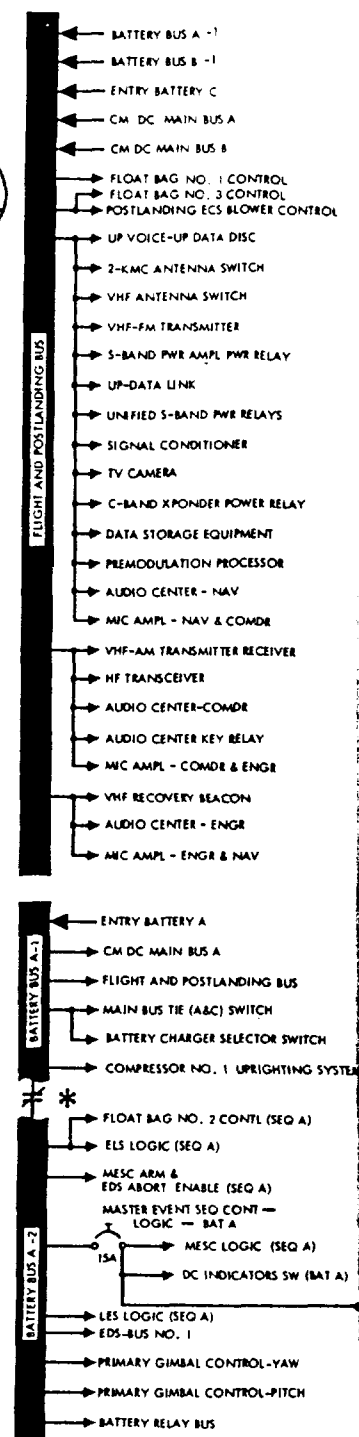
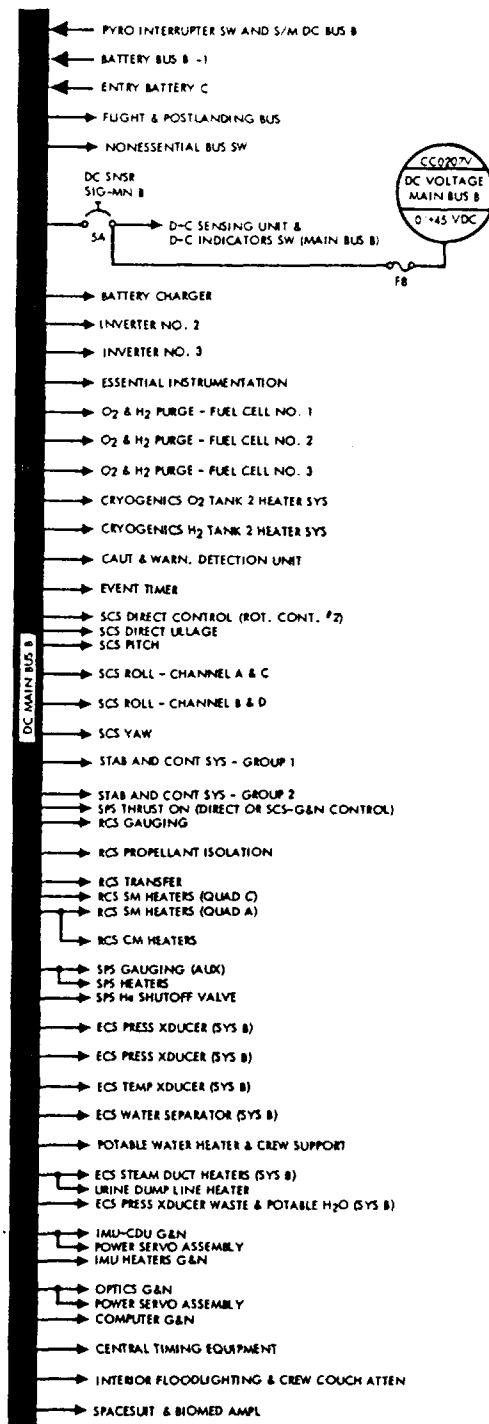
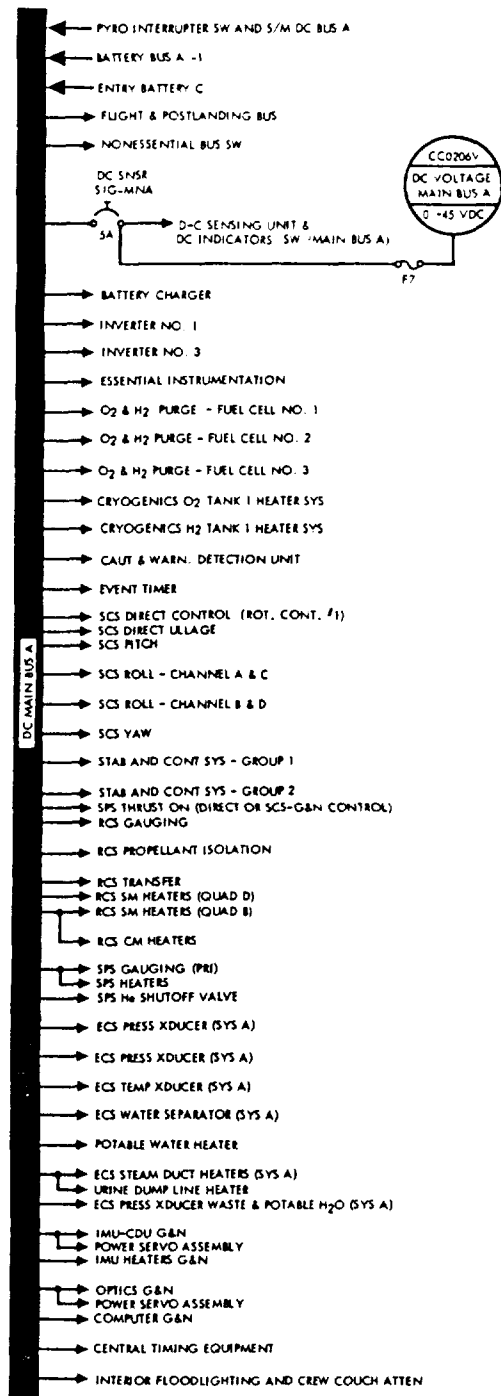
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below 26.25 volts dc, an applicable d-c undervoltage light on the caution and warning panel (MDC-11) will illuminate. Since each bus is capable of handling all EPS loads, an undervoltage condition should not occur except in an isolated instance, if too many electrical units are placed on the bus simultaneously or if a malfunction exists in the EPS. A voltmeter, on MDC-18, is provided to monitor bus voltage. An ammeter is provided on MDC-18 to monitor current output of fuel cells 1, 2, 3, batteries A, B, C, and the battery charger. During extreme power loads or emergencies, power to the main d-c buses can be supplied from entry batteries A and B by way of battery buses and directly from battery C (figure 2.6-11). Each battery bus is separated physically into two parts (e.g., battery bus A is A-1 and A-2), but remain connected electrically by motor switch contacts which are not opened on manned S/C. A switch to two nonessential buses permits isolating nonessential equipment during a shortage of power (two fuel cell power plants out). The postlanding bus supplies power to some of the telecommunications equipment, float bag No. 1 and No. 3 controls, and the ECS postlanding vent control. In flight and up to CSM separation, the postlanding bus receives power from the fuel cells and/or entry batteries through the main d-c buses. After CSM separation, the entry batteries supply power to the postlanding bus through the main d-c buses or directly through individual circuit breakers. Motor switch contacts which close when the MAIN BUS TIE switches are positioned ON, complete the circuit between the entry batteries and the main d-c buses and open the connection from the battery charger. The battery relay bus provides d-c power to the d-c and a-c sensing units, and the fuel cell and inverter control circuits. The pyrotechnic batteries supply power to initiate ordnance devices for separation of the LES, forward heat shield, S/M from C/M, and for deployment of the drogue and main parachutes during a pad abort, high-altitude abort, or normal mission progression. The S/M jettison controller batteries, supply power through the S/M jettison controllers for the CSM separation maneuver. To operate recovery communications and other aids after landing, power is provided by the entry batteries through three circuit breakers (figure 2.6-11) which are normally open until just prior to CSM separation.

Distribution of a-c power (figure 2.6-12) is accomplished with a four-wire system via two redundant buses, a-c bus No. 1 and a-c bus No. 2. The a-c neutral bus is connected to the single-point ground. A-C power is provided by the solid-state 115/200-volt 400-cps 3-phase inverters. D-C power is routed to the inverters through the main d-c buses. Inverter No. 1 can be powered through d-c main bus A, inverter No. 2 through d-c main bus B, and inverter No. 3 through either d-c main bus A or B by switch selection. Each of these circuits has a separate circuit breaker and a power control motor switch. Switches for applying power to the motor switches are located on MDC-18. All three inverters are identical and are provided with overtemperature circuitry. A light indicator, in the caution/warning group on MDC-11, illuminates to indicate an overtemperature situation. Inverter operating temperature is telemetered

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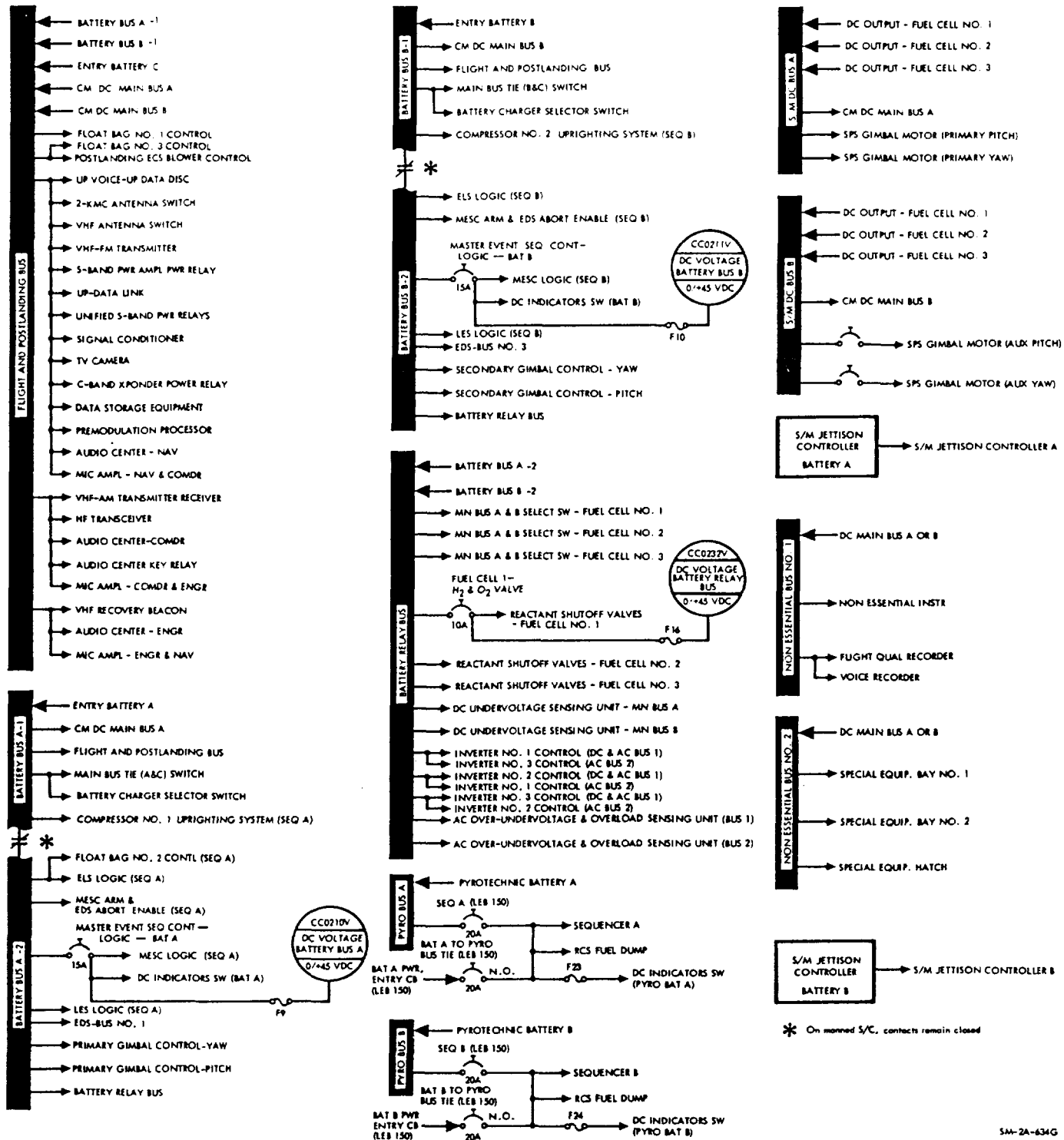


Figure 2.6-9. D-C Power Distribution

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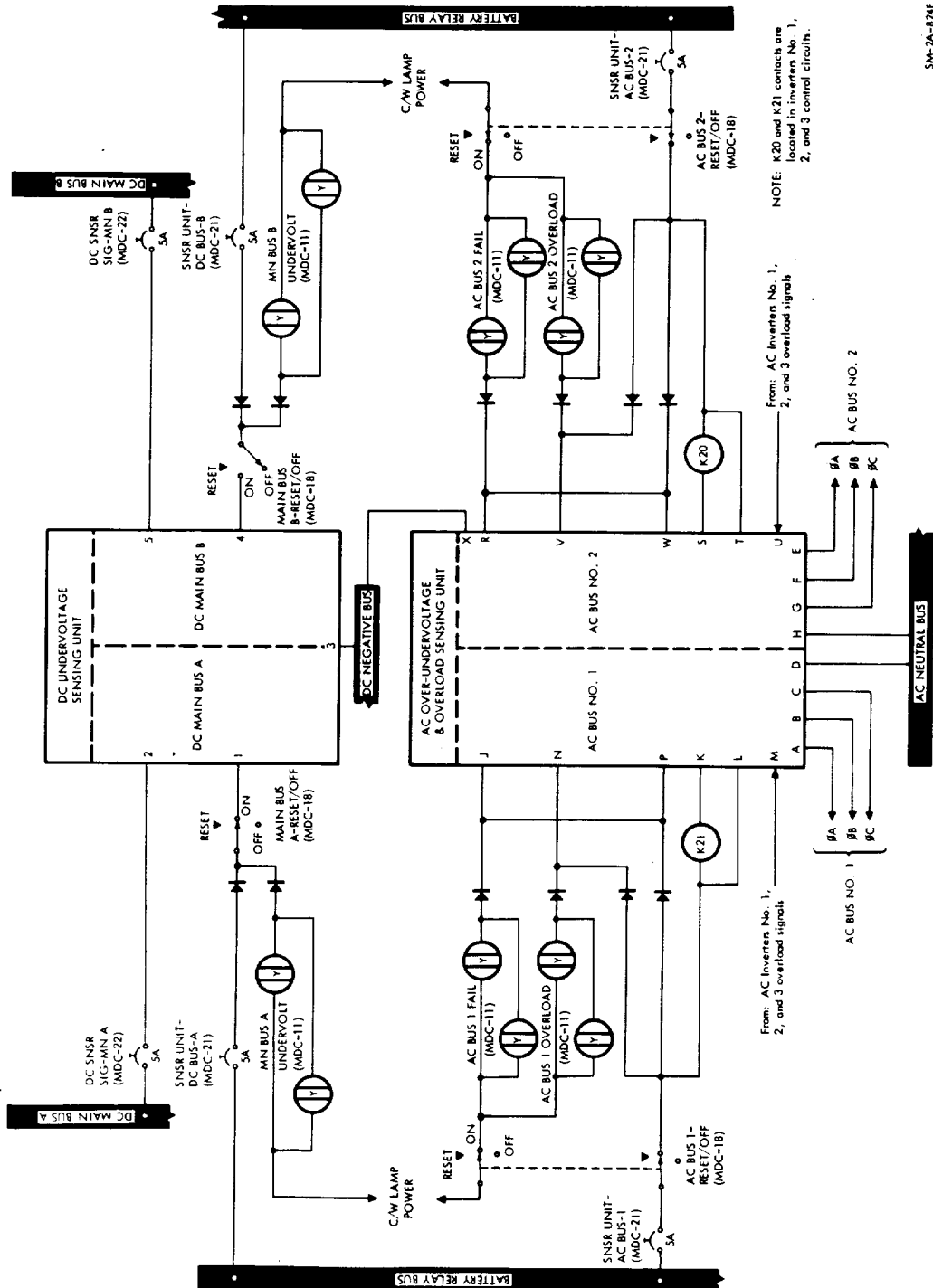


Figure 2.6-10. DC and AC Sensing Circuits

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to the MSFN. Inverter output is routed through a series of control motor switches to the a-c buses. Six switches on MDC-18 control motor switches which operate contacts to connect or disconnect the inverters from the a-c buses. The motor switches are designed to prevent connecting two inverters to the same a-c bus at the same time. AC loads are powered through the redundant a-c buses. In some instances, one phase is used for operation of equipment; in others two, and in others all three. Over-undervoltage and overload sensing circuits (figure 2.6-11) are provided for each bus. A-C bus voltage fail and overload lights in the caution/warning group on MDC-11 provide a visual indication of these malfunctions. Monitoring of voltage and frequency of each phase on each bus is accomplished by selection with the AC INDICATORS switch. Readings are displayed on separate AC VOLTS and FREQUENCY meters located on MDC-18. Each phase voltage and  $\emptyset$ A frequency is telemetered to MSFN stations.

2.6.4 PERFORMANCE AND DESIGN DATA.

2.6.4.1 AC and DC Data.

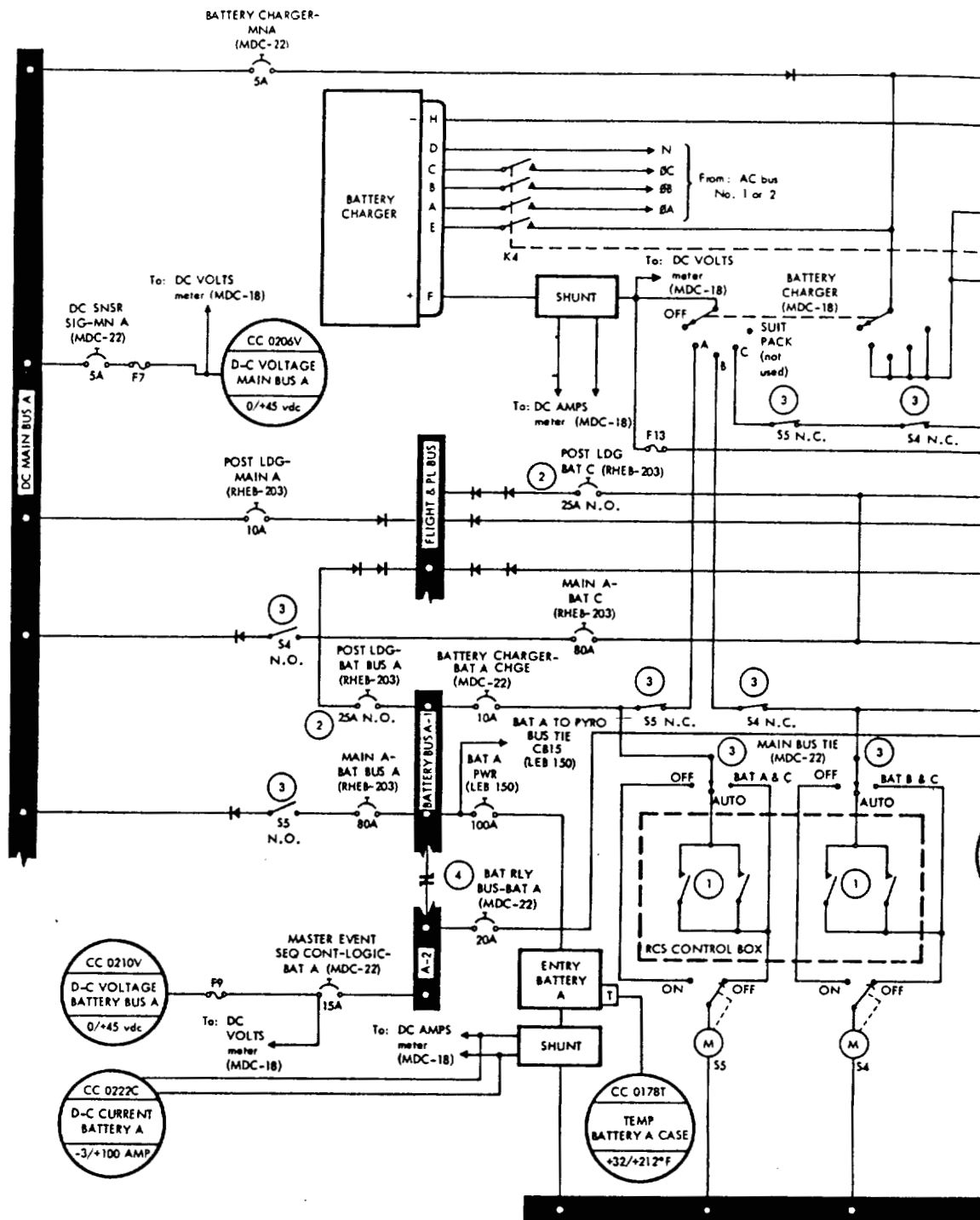
AC and DC performance and design data for the EPS is as follows:

AC

Phases	3
Displacement	120 $\pm$ 2 degrees
Steady-state voltage	115 $\pm$ 2 vac (average of 3 phases)
Transient voltage	115 (+35, -65) vac
Recovery	To 115 $\pm$ 10v within 15 ms, steady state within 50 ms
Unbalance	2 vac (worst phase from average)
Frequency limits	
Normal (synchronized to central timing equipment)	400 $\pm$ 2 cps
Emergency (loss of central timing equipment)	400 $\pm$ 7 cps
Wave characteristics (sine wave)	
Maximum distortion	5 percent
Highest harmonic	4 percent
Crest factor	1.414 $\pm$ 10 percent
Rating	1250 va

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DC

Steady-state voltage limits  
Normal 29±2.0 vdc

During postlanding and  
preflight checkout periods 27 to 30 vdc

Ripple voltage 1v p-p

2.6.4.2 Power Requirements.

Power requirements for the EPS are as follows:

Unit	Control	Unit Quantity	Unit Input Power (Watts)		Total Input Power (Watts)	
			AC	DC	AC	DC
FUEL CELLS						
Hydrogen pump	FUEL CELL PUMP-1, -2, and -3 sw (MDC-22)	3	100.0		300.0	
Glycol pump	FUEL CELL PUMP-1, -2, and -3 sw (MDC-22)	3	20.0		60.0	
pH indicator	FUEL CELL PUMP-1, -2, and -3 sw (MDC-22) and FUEL CELL INDICATORS sw (MDC-18)	3	2.0		6.0	
Power factor correction for above items		3	2.5		7.5	
Total including pf correction					373.5	
Pressure transducers	FUEL CELL INDICATORS sw (MDC-18)	9		2.0		18.0
H <sub>2</sub> flowmeter circuits	FUEL CELL INDICATORS sw (MDC-18)	3		1.0		3.0

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Unit	Control	Unit Quantity	Unit Input Power (Watts)		Total Input Power (Watts)	
			AC	DC	AC	DC
O <sub>2</sub> flowmeter circuits	FUEL CELL INDICATORS sw (MDC-18)	3		1.0		3.0
H <sub>2</sub> purge line heater	H <sub>2</sub> PURGE LINE HEATER (MDC-15)	2		2.0		4.0
Purge solenoid	FUEL CELL-1, -2, -3, and H <sub>2</sub> PURGE/O <sub>2</sub> PURGE sw (MDC-18)	6		17.5		105.0
Fuel cell inline heater	None (Automatic on at +385±5°F) (Automatic off at +390±5°F)	3		160.0		480.0
CRYOGENICS						
H <sub>2</sub> tank heater	H <sub>2</sub> HEATERS-1 and -2 sw (MDC-13)	2		20.0		40.0
O <sub>2</sub> tank heater	O <sub>2</sub> HEATERS-1 and -2 sw (MDC-13)	2		155.0		310.0
H <sub>2</sub> tank fan	H <sub>2</sub> FANS-1 and -2 sw (MDC-13)	4	5.0		20.0	
O <sub>2</sub> tank fan	O <sub>2</sub> FANS -1 and -2 sw (MDC-13)	4	14.5		58.0	
Pressure transducer	ESSENTIAL-3 (153) C/B	4		1.5		6.0
Signal conditioner	CRYOGENIC SYSTEM- QTY AMPL-1 and -2- ØC C/B (MDC-22)	4	4.0		16.0	
BATTERY CHARGER	BATTERY CHARGER selector sw (MDC-18)	1			55.0 max	84.0 max

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Unit	Control	Unit Quantity	Unit Input Power (Watts)		Total Input Power (Watts)	
			AC	DC	AC	DC
SENSING UNITS						
D-C under-voltage sensing unit(2 circuits)	MAIN BUS A and B-RESET/OFF sw (MDC-18)	1				0.5
A-C under and overvoltage and overload sensing unit (2 circuits)	AC BUS 1 and 2-RESET/OFF sw (MDC-18)	1				1.0
PHASE SYNCHRONIZER UNIT	INV PHASE LOCK (panel 208)	1	7.5		7.5	
INVERTERS (See note)	AC INVERTER-1, -2, and -3 sw (MDC-18)					

NOTE With a 28-volt d-c input, each inverter will operate at air efficiency of 76 percent minimum with a 1250 volt-ampere load, 0.9 power factor, and 74 percent minimum with a 625 volt-ampere load, 0.9 power factor.

2.6.5 OPERATIONAL LIMITATIONS AND RESTRICTIONS.

2.6.5.1 Fuel Cell Power Plants.

Fuel cell power plants are designed to function under atmospheric and high vacuum conditions. Each must be able to maintain itself at sustaining temperatures and minimum electrical loads at both environment extremes. To function properly, fuel cells must operate under the following limitations and restrictions:

- External nonoperating temperature      -20° to +140°F
- Operating temperature inside S/M      +30° to +130°F
- External nonoperating pressure      Atmospheric
- Normal voltage      27 to 31 vdc

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- Minimum operating voltage  
Emergency operation 20.5 vdc at 2295 watts  
(gross power level)
  
  - Normal operation 27 vdc
  
  - Maximum operating voltage 31 vdc
  
  - Fuel cell disconnect (overload and reverse current relay) 75 amperes for over 15 minutes, 112 amperes for 25 to 300 seconds
  
  - Maximum reverse current 1 second minimum
  
  - Minimum sustaining power/fuel cell power plant (with in-line heater off) 563 watts
  - In-line heater 160 watts
  
  - H<sub>2</sub> purge line heater 4 watts
  
  - Maximum gross power under emergency conditions 2295 watts
  
  - Nitrogen pressure 52 to 70 psia
  
  - Reactant pressure
    - Oxygen 62 to 75 psia
    - Hydrogen 60.5 to 75 psia
  
  - Reactant consumption/fuel cell power plant
 

Power Level	563W	2295W
Hydrogen	0.0476	0.262 lb/hr
Oxygen	0.378	2.08 lb/hr
  
  - Electrolyte water concentration 24.3 to 28.2 percent
  
  - Minimum stack temperature for self-sustaining operation +385°F
  
  - Approximate external environment temperature range outside S/C (for radiation) -260° to +400°F
  
  - Fuel cell power plant operating skin temperature +385° to +500°F
  
  - Condenser exhaust operating temperature +155° to +175°F
- 

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- Purging frequency  
Nominally every 24 hrs.  
(dependent on reactant purity  
after tank fill)
- O<sub>2</sub> switch ON time  
2 minutes
- H<sub>2</sub> switch ON time  
80 seconds
- Additional flow rate while purging
- O<sub>2</sub>  
Up to 0.6 lb/hr
- H<sub>2</sub>  
Up to 0.75 lb/hr

2.6.5.2 Cryogenic Storage Subsystem.

The cryogenic storage subsystem must be able to meet the following requirements for proper operation of the fuel cell power plants and the ECS:

- Minimum usable quantity
- Oxygen  
320 lb each tank
- Hydrogen  
28 lb each tank
- Temperature at time of fill
- Oxygen  
-297°F (approx)
- Hydrogen  
-423°F (approx)
- Operating pressure range
- Oxygen  
865 to 935 psia
- Hydrogen  
225 to 260 psia
- Temperature probe range
- Oxygen  
-325° to +80°F
- Hydrogen  
-425° to -200°F
- Maximum allowable difference  
in quantity balance between tanks
- Oxygen tanks No. 1 and 2  
15 lb
- Hydrogen tanks No. 1 and 2  
1 lb
- Pressure relief valve operation
- Crack pressure
- Oxygen  
998 psia
- Hydrogen  
288 psia
- Reseat pressure
- Oxygen  
980 psia
- Hydrogen  
283 psia
- Full flow, maximum relief
- Oxygen  
1025 psia
- Hydrogen  
300 psia

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2.6.6 TELEMETRY MEASUREMENTS.

The following is a complete list of all EPS telemetry data that is monitored by flight controllers and ground support personnel. The last column contains the name and type of S/C crew display. The display utilizes the same pickoff or signal source as telemetry, unless a separate measurement number is included in the display column.

An asterisk (\*) by the measurement number denotes information which is not available for recording or telemetry transmission during PCM low bit rate operation.

Measure- ment Number	Description	Sensor Range	Normal Operating Range	Crew Display
CC 0175 T	Temp static inverter 1	+32/+248°F	+40° to +140°F	INV 1 TEMP HI C&W light
CC 0176 T	Temp static inverter 2	+32/+248°F	+40° to +140°F	INV 2 TEMP HI C&W light
CC 0177 T	Temp static inverter 3	+32/+248°F	+40° to +140°F	INV 3 TEMP HI C&W light
*CC 0178 T	Temp battery A case	+32/+212°F	+50° to 110°F (200°F entry)	None
*CC 0179 T	Temp battery B case	+32/+212°F	+50° to 110°F (200°F entry)	None
*CC 0188 P	Press bat compartment (Manif)	Zero/+18 psia	Zero	Auxiliary DC VOLTS meter
CC 0200 V	AC voltage main bus 1 phase A	Zero/+150 vac	113 to 117 vac	AC VOLTS meter
*CC 0201 V	AC voltage main bus 1 phase B	Zero/+150 vac	113 to 117 vac	AC VOLTS meter
*CC 0202 V	AC voltage main bus 1 phase C	Zero/+150 vac	113 to 117 vac	AC VOLTS meter
CC 0203 V	AC voltage main bus 2 phase A	Zero/+150 vac	113 to 117 vac	AC VOLTS meter
*CC 0204 V	AC voltage main bus 2 phase B	Zero/+150 vac	113 to 117 vac	AC VOLTS meter
*CC 0205 V	AC voltage main bus 2 phase C	Zero/+150 vac	113 to 117 vac	AC VOLTS meter
CC 0206 V	DC voltage main bus A	Zero/+45 vdc	27 to 31 vdc	DC VOLTS meter
CC 0207 V	DC voltage main bus B	Zero/+45 vdc	27 to 31 vdc	DC VOLTS meter
*CC 0210 V	DC voltage battery bus A	Zero/+45 vdc	35 to 37 vdc open circuit	DC VOLTS meter
*CC 0211 V	DC voltage battery bus B	Zero/+45 vdc	27 to 29 vdc on load	DC VOLTS meter

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Measure- ment Number	Description	Sensor Range	Normal Operating Range	Crew Display
*CC 0212 V	DC voltage post landing battery	Zero/+45 vdc	35 to 37.2 vdc open circuit 27 to 29 vdc on load	DC VOLTS meter
*CC 0213 F	Frequency ac bus 1 phase A	+380/+420 cps	393 to 407 cps	FREQUENCY meter
*CC 0214 V	DC voltage bat charger out	Zero/+45 vdc	37 to 39 vdc	DC VOLTS meter
*CC 0217 F	Frequency ac bus 2 phase A	+380/+420 cps	393 to 407 cps	FREQUENCY meter
*CC 0222 C	DC current battery A	-3/+100 amp	-3 to 30 amps	DC AMPS meter
*CC 0223 C	DC current battery B	-3/+100 amp	-3 to 30 amps	DC AMPS meter
*CC 0224 C	DC current post landing battery	-3/+100 amp	-3 to 30 amps	DC AMPS meter
CC 0232 V	DC voltage battery relay bus	Zero/+45 vdc	25 to 36.5 vdc	None
*SC 2060 P	N <sub>2</sub> pressure F/C 1 regulated	Zero/+75 psia	50 to 54 psia	F/C 1 C&W light, REG OUT PRESS HI-N <sub>2</sub> event indi- cator, and auxil- iary DC VOLTS meter.
*SC 2061 P	N <sub>2</sub> pressure F/C 2 regulated	Zero/+75 psia	50 to 54 psia	F/C 2 C&W light, REG OUT PRESS HI-N <sub>2</sub> event indi- cator, and auxil- iary DC VOLTS meter
*SC 2062 P	N <sub>2</sub> pressure F/C 3 regulated	Zero/+75 psia	50 to 54 psia	F/C 3 C&W light, REG OUT PRESS HI-N <sub>2</sub> event indi- cator, and auxil- iary DC VOLTS meter
*SC 2066 P	O <sub>2</sub> pressure F/C 1 regulated	Zero/+75 psia	59 to 65 psia	F/C 1 C&W light, REG OUT PRESS HI-O <sub>2</sub> event indi- cator, and auxil- iary DC VOLTS meter
*SC 2067 P	O <sub>2</sub> pressure F/C 2 regulated	Zero/+75 psia	59 to 65 psia	F/C 2 C&W light, REG OUT PRESS HI-O <sub>2</sub> event indi- cator, and auxil- iary DC VOLTS meter

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Measure- ment Number	Description	Sensor Range	Normal Operating Range	Crew Display
*SC 2068 P	O <sub>2</sub> pressure F/C 3 regulated	Zero/+75 psia	59 to 65 psia	F/C 3 C&W light, REG OUT PRESS HI-O <sub>2</sub> event indicator, and auxiliary DC VOLTS meter
*SC 2069 P	H <sub>2</sub> pressure F/C 1 regulated	Zero/+75 psia	57.5 to 63.5 psia	F/C 1 C&W light, REG OUT PRESS HI-H <sub>2</sub> event indicator, and auxiliary DC VOLTS meter
*SC 2070 P	H <sub>2</sub> pressure F/C 2 regulated	Zero/+75 psia	57.5 to 63.5 psia	F/C 2 C&W light, REG OUT PRESS HI-H <sub>2</sub> event indicator, and auxiliary DC VOLTS meter
*SC 2071 P	H <sub>2</sub> pressure F/C 3 regulated	Zero/+75 psia	57.5 to 63.5 psia	F/C 3 C&W light, REG OUT PRESS HI-H <sub>2</sub> event indicator, and auxiliary DC VOLTS meter
SC 2081 T	Temp F/C 1 cond exhaust	+150/+250°F	+157° to +172°F	F/C 1 C&W light, and MODULE TEMP COND-EXH indicator
SC 2082 T	Temp F/C 2 cond exhaust	+150/+250°F	+157° to +172°F	F/C 2 C&W light, and MODULE TEMP COND-EXH indicator
SC 2083 T	Temp F/C 3 cond exhaust	+150/+250°F	+157° to +172°F	F/C 3 C&W light, and MODULE TEMP COND-EXH indicator
SC 2084 T	Temp F/C 1 skin	+80/+550°F	+385° to +460°F	F/C 1 C&W light and MODULE TEMP-SKIN indicator
SC 2085 T	Temp F/C 2 skin	+80/+550°F	+385° to +460°F	F/C 2 C&W light and MODULE TEMP-SKIN indicator

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Measure- ment Number	Description	Sensor Range	Normal Operating Range	Crew Display
SC 2086 T	Temp F/C 3 skin	+80/+550°F	+385° to +460°F	F/C 3 C&W light and MODULE TEMP-SKIN indicator
SC 2087 T	Temp F/C 1 radiator outlet	-50/+300°F	-30° to +300°F	F/C 1 C&W light, F/C RAD TEMP LOW event indica- tor and auxiliary DC VOLTS meter
SC 2088 T	Temp F/C 2 radiator outlet	-50/+300°F	-30° to +300°F	F/C 2 C&W light, F/C RAD TEMP LOW event indica- tor and auxiliary DC VOLTS meter
SC 2089 T	Temp F/C 3 radiator outlet	-50/+300°F	-30° to +300°F	F/C 3 C&W light, F/C RAD TEMP LOW event indica- tor and auxiliary DC VOLTS meter
SC 2113 C	DC current F/C 1 output	Zero/+100 amps	18 to 22 amps	DC AMPS meter
SC 2114 C	DC current F/C 2 output	Zero/+100 amps	18 to 22 amps	DC AMPS meter
SC 2115 C	DC current F/C 3 output	Zero/+100 amps	18 to 22 amps	DC AMPS meter
SC 2120 X	Fuel cell 1 bus A disconnect	Off/on event	Connected	F/C BUS DISCON- NECT C&W light and FUEL CELL-1- MAIN BUS A switch event indicator
SC 2121 X	Fuel cell 2 bus A disconnect	Off/on event	Connected	F/C BUS DISCON- NECT C&W light and FUEL CELL-2- MAIN BUS A switch event indicator
SC 2122 X	Fuel cell 3 bus A disconnect	Off/on event	Disconnected	F/C BUS DISCON- NECT C&W light and FUEL CELL-3- MAIN BUS A switch event indicator

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Measure- ment Number	Description	Sensor Range	Normal Operating Range	Crew Display
SC 2125 X	Fuel cell 1 bus B disconnect	Off/on event	Disconnected	F/C BUS DISCON- NECT C&W light and FUEL CELL-1- MAIN BUS B switch event indicator
SC 2126 X	Fuel cell 2 bus B disconnect	Off/on event	Connected	F/C BUS DISCON- NECT C&W light and FUEL CELL-2- MAIN BUS B switch event indicator
SC 2127 X	Fuel cell 3 bus B disconnect	Off/on event	Connected	F/C BUS DISCON- NECT C&W light and FUEL CELL-3- MAIN BUS B switch event indicator
*SC 2139 R	Flow rate H <sub>2</sub> F/C 1	Zero/+0.2 lb/hr	0.046 to 0.056 lbs/hr	F/C 1 C&W light and FLOW-H <sub>2</sub> indicator
*SC 2140 R	Flow rate H <sub>2</sub> F/C 2	Zero/+0.2 lb/hr	0.046 to 0.056 lbs/hr	F/C 2 C&W light and FLOW-H <sub>2</sub> indicator
*SC 2141 R	Flow rate H <sub>2</sub> F/C 3	Zero/+0.2 lb/hr	0.046 to 0.056 lbs/hr	F/C 3 C&W light and FLOW-H <sub>2</sub> indicator
*SC 2142 R	Flow rate O <sub>2</sub> F/C 1	Zero/+1.6 lb/hr	0.370 to 0.450 lbs/hr	F/C 1 C&W light and FLOW-O <sub>2</sub> indicator
*SC 2143 R	Flow rate O <sub>2</sub> F/C 2	Zero/+1.6 lb/hr	0.370 to 0.450 lbs/hr	F/C 2 C&W light and FLOW-O <sub>2</sub> indicator
*SC 2144 R	Flow rate O <sub>2</sub> F/C 3	Zero/+1.6 lb/hr	0.370 to 0.450 lbs/hr	F/C 3 C&W light and FLOW-O <sub>2</sub> indicator
*SC 2160 X	pH factor water condi- tion F/C 1	Normal/high event	Normal	F/C 1 C&W light and pH HI event indicator
*SC 2161 X	pH factor water condi- tion F/C 2	Normal/high event	Normal	F/C 2 C&W light and pH HI event indicator
*SC 2162 X	pH factor water condi- tion F/C 3	Normal/high event	Normal	F/C 3 C&W light and pH HI event indicator

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Measure- ment Number	Description	Sensor Range	Normal Operating Range	Crew Display
SC 2323 X	Fuel cell 1 shut off mon	Close/open event	Open	FUEL CELL REACTANTS event indicator
SC 2324 X	Fuel cell 2 shut off mon	Close/open event	Open	FUEL CELL REACTANTS event indicator
SC 2325 X	Fuel cell 3 shut off mon	Close/open event	Open	FUEL CELL REACTANTS event indicator
SF 0030 Q	Quantity H <sub>2</sub> tank 1	Zero/+28 lb	+28 lbs to zero	TANK QUANTITY- H <sub>2</sub> -1 indicator
SF 0031 Q	Quantity H <sub>2</sub> tank 2	Zero/+28 lb	+28 lbs to zero	TANK QUANTITY- H <sub>2</sub> -2 indicator
SF 0032 Q	Quantity O <sub>2</sub> tank 1	Zero/+320 lb	+320 lbs to zero	TANK QUANTITY- O <sub>2</sub> -1 indicator
SF 0033 Q	Quantity O <sub>2</sub> tank 2	Zero/+320 lb	+320 lbs to zero	TANK QUANTITY- O <sub>2</sub> -2 indicator
SF 0037 P	Press O <sub>2</sub> tank 1	+50/+1050 psia	865 to 935 psia	O <sub>2</sub> PRESS C&W light and TANK PRESSURE-O <sub>2</sub> -1 indicator
SF 0038 P	Press O <sub>2</sub> tank 2	+50/+1050 psia	865 to 935 psia	O <sub>2</sub> PRESS C&W light and TANK PRESSURE-O <sub>2</sub> -2 indicator
SF 0039 P	Press H <sub>2</sub> tank 1	Zero/+350 psia	225 to 260 psia	H <sub>2</sub> PRESS C&W light and TANK PRESSURE-H <sub>2</sub> -1 indicator
SF 0040 P	Press H <sub>2</sub> tank 2	Zero/+350 psia	225 to 260 psia	H <sub>2</sub> PRESS C&W light and TANK PRESSURE-H <sub>2</sub> -2 indicator
SF 0041 T	Temp O <sub>2</sub> tank 1	-325/+80°F	-284° to -140°F	None
SF 0042 T	Temp O <sub>2</sub> tank 2	-325/+80°F	-284° to -140°F	None
SF 0043 T	Temp H <sub>2</sub> tank 1	-425/-200°F	-417° to -340°F	None
SF 0044 T	Temp H <sub>2</sub> tank 2	-425/-200°F	-417° to -340°F	None

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The auxiliary DC VOLTS meter, FUNCTION SELECT and TEST SELECT switches, located on panel 200 in the C/M RHFEF, provide a means of monitoring various telemetered measurements within the S/C and verifying certain parameters displayed only by event indicators. The following list presents the measurements test can be monitored using the auxiliary DC VOLTS meter, their respective switch positions, and the range of each sensor. Normal operating parameters of measurable items are covered in the telemetry listing.

Auxiliary DC VOLTS Meter Indication (Telemetry Identity and Code No.)	Switch Positions		Sensor Range
	Function Select	Test Select	
N <sub>2</sub> pressure, psia F/C 1 SC 2060 P F/C 2 SC 2061 P F/C 3 SC 2062 P	A	1 2 3	0 to 75 psia
O <sub>2</sub> pressure, psia F/C 1 SC 2066 P F/C 2 SC 2067 P F/C 3 SC 2068 P		4 5 6	0 to 75 psia
H <sub>2</sub> pressure, psia F/C 1 SC 2069 P F/C 2 SC 2070 P F/C 3 SC 2071 P		7 8 9	0 to 75 psia
EPS radiator outlet temp F/C 1 SC 2087 T F/C 2 SC 2088 T F/C 3 SC 2089 T		10 11 12	-50° to +300°F
C/M-RCS oxidizer valve temp -P engine, sys A CR 2205 T +Y engine, sys B CR 2203 T -P engine, sys B CR 2204 T CW engine, sys B CR 2206 T CCW engine, sys A CR 2201 T -Y engine, sys A CR 2202 T	B	1 2 3 4 11 12	-50° to +250°F
PIPA temp CG 2300 T		5	+125° to +135°F
IRIG temp CG 2301 T		6	+128.5° to +138.5°F

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Auxiliary DC VOLTS Meter Indication (Telemetry Identity and Code No.)	Switch Positions		Sensor Range
	Function Select	Test Select	
IMU current Heater CG 2302 C Blower CG 2303 C		7 8	0 to 5 amps
Battery manifold Pressure, psia CC 0188 P		9	0 to 18 psia
ECS radiator inlet Temp SF 0665 T		10	+60° to +150°F

The conversion of the previously listed telemetry measurements  
to the auxiliary DC VOLTS meter indication is presented as follows:

Aux- iliary DC VOLTS Meter Display	N <sub>2</sub> , O <sub>2</sub> , H <sub>2</sub> Pressure (PSIA)	EPS Radiator Outlet Temp (°F)	C/M- RCS Oxidizer Valve Temp (°F)	PIPA Temp (°F)	IRIG Temp (°F)	IMU Heater and Blower Current (Amps)	Battery Manifold Pressure (PSIA)	ECS Radiator Inlet Temp (°F)
0.0	0	-50	-50	+125.0	+128.5	0.0	0.00	+60.0
0.2	3	-36	-38	+125.4	+128.9	0.2	0.72	+63.6
0.4	6	-22	-26	+125.8	+129.3	0.4	1.44	+67.2
0.6	9	-8	-14	+126.2	+129.7	0.6	2.16	+70.8
0.8	12	+6	-2	+126.6	+130.1	0.8	2.88	+74.4
1.0	15	+20	+10	+127.0	+130.5	1.0	3.60	+78.0
1.2	18	+34	+22	+127.4	+130.9	1.2	4.32	+81.6
1.4	21	+48	+34	+127.8	+131.3	1.4	5.04	+85.2
1.6	24	+62	+46	+128.2	+131.7	1.6	5.76	+88.8
1.8	27	+76	+58	+128.6	+132.1	1.8	6.48	+92.4
2.0	30	+90	+70	+129.0	+132.5	2.0	7.20	+96.0
2.2	33	+104	+82	+129.4	+132.9	2.2	7.92	+99.6
2.4	36	+118	+94	+129.8	+133.3	2.4	8.64	+103.2
2.6	39	+132	+106	+130.2	+133.7	2.6	9.36	+106.8
2.8	42	+146	+118	+130.6	+134.1	2.8	10.08	+110.4
3.0	45	+160	+130	+131.0	+134.5	3.0	10.80	+114.0
3.2	48	+174	+142	+131.4	+134.9	3.2	11.52	+117.6
3.4	51	+188	+154	+131.8	+135.3	3.4	12.24	+121.2
3.6	54	+202	+166	+132.2	+135.7	3.6	12.96	+124.8
3.8	57	+216	+178	+132.6	+136.1	3.8	13.68	+128.4
4.0	60	+230	+190	+133.0	+136.5	4.0	14.40	+132.0

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Aux- iliary DC VOLTS Meter Display	N <sub>2</sub> , O <sub>2</sub> , H <sub>2</sub> Pressure (PSIA)	EPS Radiator Outlet Temp (°F)	C/M- RCS Oxidizer Valve Temp (°F)	PIPA Temp (°F)	IRIG Temp (°F)	IMU Heater and Blower Current (Amps)	Battery Manifold Pressure (PSIA)	ECS Radiator Inlet Temp (°F)
4.2	63	+244	+202	+133.4	+136.9	4.2	15.12	+135.6
4.4	66	+258	+214	+133.8	+137.3	4.4	15.84	+139.2
4.6	69	+272	+226	+134.2	+137.7	4.6	16.56	+142.8
4.8	72	+286	+238	+134.6	+138.1	4.8	17.28	+146.4
5.0	75	+300	+250	+135.0	+138.5	5.0	18.00	+150.0

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SECTION 2

SUBSECTION 2.7

ENVIRONMENTAL CONTROL SYSTEM (ECS)

2.7.1 INTRODUCTION.

The environmental control system (ECS) is designed to provide a controlled environment for three crewmen within the Apollo C/M for missions up to 14 days. The system also supplies several of the metabolic requirements, as well as functioning in the removal of by-products resulting from the normal metabolic process. The controlled environment consists of a pressure suit circuit for use during normal or emergency conditions, and a shirtsleeve atmosphere within the C/M cabin, for use when normal conditions prevail. Oxygen and thermally controlled water are supplied for crew consumption; whereas, carbon dioxide and odors, water-production, and heat output are removed. In addition, the ECS disperses equipment heat loads and provides for venting the waste storage compartment. Controls and displays are located in several areas within the C/M cabin; these, in conjunction with automatically functioning components, and sensing and protective devices, aid the crew in the operation of the system. The five subsystems composing the ECS are the oxygen supply, pressure suit circuit, cabin pressure and temperature control, water-glycol coolant, and water supply.

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The oxygen supply subsystem controls the inflow of oxygen for the entire Apollo mission. This function is accomplished by pressure regulator, demand regulators, storage tanks, check valves, and manual shutoff valves. The pressure suit subsystem automatically controls the flow, pressure, temperature, and composition of the pressure suit gas. In conjunction with the C/M pressure and temperature control subsystem, it also controls the environment conditions in the cabin when one, or all of the crew are out of their pressure suits. These functions are provided by water separators, temperature controls, a suit heat exchanger, a debris trap, gas compressor, CO<sub>2</sub>-odor absorbers, and a water glycol-to-gas heat exchanger.

The cabin pressure and temperature control subsystem automatically maintains the pressure and temperature of the cabin within specified limits. This function is accomplished in conjunction with the pressure suit subsystem by means of regulated oxygen inflow, recirculation blowers, a heat exchanger, a temperature control and sensors, vent valves, and other valves and controls required. The water-glycol subsystem is an intermediate heat transfer loop which permits excess heat to be transferred from the C/M interior to the space radiators where it is rejected to the cosmic sink. This function is accomplished by pumps, heat exchangers,

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cold plate networks, valves, and controls. The water supply subsystem collects, stores, and provides water for supplemental heat transfer operation, and collects and stores potable water for consumption by the crew. These functions are accomplished by utilizing water tanks, pressure controls, cyclic accumulators, and valves.

Other than the circuitry required for controls and displays or electrical power, three points of interface exist between the ECS and other S/C systems. All oxygen supplied to the ECS flows from the cryogenic storage tanks, which are considered a part of the EPS. The fuel cells, also a part of the EPS, furnish the onboard supply of potable water that is stored by the ECS. The third interface point is with the waste management system, which connects into the ECS overboard dump line.

2.7.2 FUNCTIONAL DESCRIPTION.

The ECS requires a minimum amount of crew time be spent for normal system operation. In addition to periodically monitoring system indicators, the crew is responsible for the accomplishment of several normal tasks on an infrequent basis. For conditions other than normal, the duties of the crew will increase. Electrical and manual override and backup capabilities exist throughout the ECS to maintain the required reliability level of the system.

The oxygen supplied to the ECS from the storage tanks in the S/M is used to carry out a variety of system functions. Upon reaching the ECS, oxygen is automatically regulated and manually routed to various subsystem components by a system of valves and lines. Also incorporated are automatically functioning components to maintain suit and/or cabin pressure in the event of cabin decompression or equipment malfunction.

The atmosphere of the pressurized cabin, as well as that of the pressure garment assemblies (PGA), is routed through the suit circuit for contaminant removal and humidity control. The flow, pressure, and temperature control within the suit circuit, are maintained by other components of the subsystem. This is accomplished automatically by using transducers, sensors, and control units to regulate these functions. Mechanical-type oxygen pressure regulators automatically maintain cabin pressure within prescribed limits. The temperature of the cabin is controlled by an automatic unit that regulates the output of the cabin heat exchanger with the aid of sensors and anticipators.

Carbon dioxide and odors are removed from the suit circuit and cabin gases by routing the gas flow through two filters in the CO<sub>2</sub>-odor absorber canisters. Each filter contains sufficient lithium hydroxide (CO<sub>2</sub> removal) and activated charcoal (odor removal) for a 12-hour duty period for a crew of three. The suit circuit and cabin atmospheres are also sampled by a gas chromatograph that will identify up to 28 gas components that may be present.

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Heat, generated by the crew and the many items of electrical equipment located in the cabin, is absorbed by recirculating water-glycol. The heat is transferred to the water-glycol as it flows through the suit heat exchanger, the cabin heat exchanger, and the cold plate network for the electrical equipment. The warm water-glycol is then routed through space radiators in the S/M, where the heat is radiated to space. Supplementing the radiators and/or as a backup mode, water evaporators are employed for any additional temperature control of suit gases or insufficiently cooled water-glycol.

Potable and waste water are generated on-board the S/C. The potable water is a by-product of the EPS fuel cells and flows to the ECS where it is stored. Cold potable water is available to the crew for drinking, and hot or cold potable water is available for food reconstitution. Waste water is derived from the moisture that condenses in the water separator of the suit exchanger. It is collected and stored by the ECS and used for evaporative cooling in the suit heat exchanger evaporator and the water-glycol evaporator.

2.7.3 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

Pertinent design data in regard to components, their function within each subsystem, and how they interface is contained under major component/subsystem description. The description follows the logical flow, component by component, through each subsystem of the ECS.

2.7.3.1 Oxygen Supply Subsystem.

Two cryogenic oxygen storage tanks (part of the electrical power system) supply 900±35 psia oxygen flow to the ECS. Each tank contains 320 pounds of oxygen, and of the total supply, approximately one-third is consumed by the ECS. Oxygen flows unrestricted in parallel lines from the S/M supply tanks into the C/M. In the C/M, oxygen flows in each supply line through a filter, a capillary restrictor, and a check valve upstream to their connection to a common distribution line. To assure uniform flow, the capillary restrictors are coiled around a warm water-glycol line to increase the oxygen temperature. Each restrictor allows a maximum flow of 4.5 pounds per hour into the ECS to limit the demands placed on the cryogenic oxygen storage tanks and enable the tank heaters to maintain the prescribed tank pressures. The minimum flow rate will not decrease below 3.4 pounds per hour as the oxygen density decreases due to usage. Illustrated in the ECS integrated schematic (figure 2.7-13) the manual S/M supply shutoff valve, located on the LHEB panel 307, is normally in the ON position and placed to OFF prior to SCM separation for the entry phase of the mission. Downstream of the S/M shutoff valve 900±35 psia oxygen is distributed to a surge tank, an entry O<sub>2</sub> tank, a PLSS fill valve, and the main pressure regulator assembly. Oxygen flows to the surge tank through a manual surge tank isolation valve, located on the LHEB panel 307. The surge tank provides a reservoir of O<sub>2</sub> for the entry mission modes, and during flow requirements above the 0.9 pound per hour maximum

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allowable by the capillary restrictors. Approximately 3.7 pounds of oxygen is available at nominal inlet pressure of  $900 \pm 35$  psia. A surge tank pressure transducer output is displayed by the TANK PRESS  $O_2$  1 indicator, located on MDC panel 13. The indicator input must be selected by the switch position, SURGE TANK, located below the indicator. To reduce the demand loads on the cryogenic storage system, high flow rates from the surge tank will maintain cabin pressure from 5 to 3.5 psia for 5 minutes, with a 0.5-inch-diameter puncture in the cabin. The flow rate into the cabin is a function of regulator valves downstream of the surge tank. The 5-minute period allows unsuited crewmembers to don PGAs. When isolated by the surge tank manual shutoff valve, the tank is protected by a pressure relief and manual shutoff valve assembly. The relief portion is set between 1020 and 1070 psig. Should the relief valve fail or not reseal properly, the manual shutoff valve will isolate the relief valve function from the system.

Downstream  $O_2$  supply is also stored in a one-pound entry  $O_2$  tank, through a manual three-way selector valve, a check valve, and a check valve bypass. When the manual selector valve is in the FILL position, the entry  $O_2$  supply tank receives high pressure  $O_2$  through the check valve bypass. When the tank is charged, the selector valve may be positioned to OFF to isolate the tank supply, or to ON whereby the  $O_2$  tank supply may augment the surge tank function. The check valve prevents a reverse flow in case of entry  $O_2$  tank damage. An isolation check valve between the two tanks prevents reverse flow and a manual valve permits charging PLSS oxygen tanks from the ECS.

The  $900 \pm 35$ -psig oxygen supply, from the cryogenic tanks, is regulated to  $100 \pm 10$  psig by the main pressure regulator assembly illustrated in figure 2.7-1. The main pressure regulator assembly consists of a manual selector valve, two regulators, and two relief and check valves. NORMAL position of the manual selector valve parallels the regulators. Position No. 1 or No. 2 selects its regulator respectively. The OFF position isolates all  $O_2$  supply for the crew and cabin. Should a regulator fail open, the relief valve for that regulator will limit the pressure to 140 psig downstream and vent a maximum flow of 0.75 pounds per minute into the cabin. This fault should be corrected by selecting the alternate regulator only.

An oxygen flow transducer, downstream of the main regulator, provides a signal to the flow indicator, located on the main display console panel 13, and the  $O_2$  FLOW HI light. Although short periods of flow in excess of 0.45 pounds per hour are considered normal, a continuous flow rate between 0.45 and 1.0 pound per hour should not be tolerated. Flow rates above 1.0 pounds per hour and for a period of 15 seconds and above activate the red  $O_2$  FLOW HI warning light located on the caution and warning (C&W) panel 11. The 15-second time delay prevents the  $O_2$  FLOW HI light from lighting during  $O_2$  flow requirements of the cyclic accumulators that remove water from the suit heat exchanger, and during transient conditions. Continued flow rates in this range are indicative of cabin leakage,  $O_2$  supplied subsystem leakage, or subsystem mismanagement.

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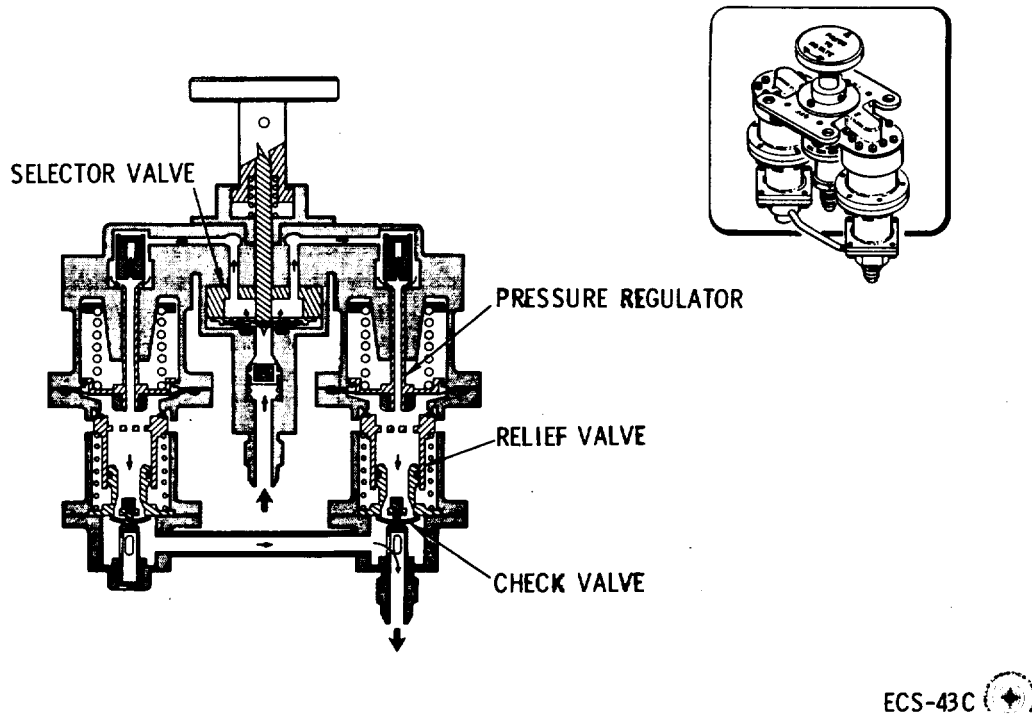


Figure 2.7-1. Main Oxygen Pressure Regulator

Connected to the  $100 \pm 10$ -psig regulated pressure line is a fluid tank pressure regulator and relief valve assembly, located on the OXYGEN CONTROL PANEL No. 314. It consists of redundant pressure regulators and relief valves which provide oxygen at regulated pressure to the expulsion bladders installed in the potable water tank, waste water tank, and the water-glycol (W/G) reservoir. Two four-position selector valves are employed at the inlet and outlet, and enable isolation of malfunctioning elements or complete shutoff as desired. The pressure regulator is a normally opened, diaphragm-operated poppet metering valve which functions to reduce  $100 \pm 10$ -psig supply pressure to  $20 \pm 2$ -psig  $O_2$  pressure to the fluid tanks, in relation to cabin pressure. The relief valve incorporated in the assembly outlet chamber functions to relieve  $O_2$  pressure in excess of  $25 \pm 2$  psig into the cabin.

Should a regulator diaphragm rupture, and is isolated by the inlet manual selector valve, the manual outlet selector valve must also be positioned to isolate the relief portion of the failed regulator. This prevents a feedback from the alternate regulator flowing oxygen through the ruptured diaphragm of the failed regulator into the cabin.

Should the selector inlet valve of the assembly be placed to position 1, the selector outlet valve must also be placed to position 1 (or NORMAL). If instead, the selector outlet valve were placed to position 2, the valve port to pressurize the tanks would be closed, and the port to the relief

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valve would remain open. This permits the pressure relief function of the valve to remain operative but prohibits subsequent tank pressurization. Conversely, when the selector outlet valve is set to position 2, the selector inlet valve must also be set to position 2 (or NORMAL). The OFF position of the inlet and outlet selector valves is normally for ground checkout; however, if both pressure regulators malfunction during flight, the selector inlet valve must be set to the OFF position. This eliminates the tank pressurization function, but does not affect the pressure relief function. In response to the possibility of both relief valves malfunctioning, the selector outlet valve must be set to the OFF position. This action will eliminate both the pressurization and pressure relief functions.

The 100±10-psig oxygen supply is controlled by the emergency cabin pressure regulator, located on panel 314, to provide increased oxygen flow to the cabin, and prevent rapid decompression. The emergency cabin pressure regulator consists of dual aneroid-operated, normally closed valves to prevent overpressurization of the aneroids, and a manual four-position selector valve with positions designated No. 1, No. 2, NORMAL, and OFF. A PRESS-TO-TEST button, which closes the cabin pressure sense port allows a fix bleed of 100 cc per min to pressurize an aneroid chamber and drive the valve open. Normally the 100±10-psig oxygen supply to the cabin is controlled by the cabin pressure regulator assembly. It consists of dual, aneroid-absolute type normally closed valves, and each will deliver a minimum of 0.2 pound per hour oxygen flow at a cabin pressure of 5.0±0.2 psia. Failure mode of the valve is normally closed. A manual control valve may be opened and allow a minimum 6 pounds per hour flow of O<sub>2</sub> directly into the cabin for repressurization from 0.0 to 5.0 psia within one hour. The cabin pressure regulator and the emergency cabin pressure regulator are associated with the cabin pressure and temperature control subsystem (paragraph 2.7.3.3). Oxygen distribution at 100±10 psig is routed to a manually operated metering valve, for direct flow into the suit inlet duct. In the full open position, oxygen will flow from 0.6 to 0.7 pound per minute.

Downstream the dual suit demand pressure regulator and relief valve, located on LHEB panel 310, compares suit compressor inlet pressure to cabin ambient pressure. When the compressor inlet pressure is 2.5 to 3.5 inches of water pressure below cabin pressure, the demand regulator controls O<sub>2</sub> flow into the suit circuit at flow rates up to 0.007 pound per minute. When the compressor inlet pressure is above 2 to 9 inches of water pressure above cabin pressure, the relief valve vents the suit circuit gases to the cabin at a maximum flow rate of 0.66 pound per minute. Normally the compressor inlet manifold is regulated to an average of 6.10 inches of water above cabin ambient pressure. When cabin ambient pressure is less than 4 psia, a 100 ccm bleed within the demand regulator is used to maintain the suit circuit pressure at 3.75±0.25 psia. With cabin ambient pressure below 3.5 psia and a 0.66 pound per minute suit leakage, the demand regulator should sustain suit circuit pressure at 3.75±0.25 psia. A four-position manual selector valve with control positions designated as No. 1, No. 2, both, and OFF provides isolation of a fault. The demand pressure regulator and relief valve are described in paragraph 2.7.3.3.

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Oxygen regulated at  $100 \pm 10$ -psig pressure is used as a motive force in the removal of waste water from the suit circuit and then expelled into the suit heat exchanger.

2.7.3.2 Pressure Suit Circuit Subsystem.

The pressure suit subsystem is a loop or circuit designed to supply a conditioned atmosphere for a crew of three, whether they be in or out of their PGAs. The circuit provides for ventilation and cooling for the crew, the removal of carbon dioxide and odors, and the control of relative humidity. Suit circuit pressure is maintained by controlling the amount of oxygen entering the subsystem.

A supply-return hose assembly is connected between each crewman's PGA and a suit hose connector assembly. This assembly consists of a combined supply-return connection. A three-position suit flow control valve, which diverts oxygen into the cabin when a crewmember is unsuited, and a check valve prevents return flow from the cabin. Normal operation is to disconnect the hose at the suit. There is also a venturi-type flow limiter, located upstream in each supply line, to limit flow to any one suit to a maximum of 0.7 pound per minute. During the time a crewmember is in the shirtsleeve mode, the flow control valve is positioned to permit suit circuit flow into the C/M cabin, through the suit hose, which is removed at the PGA connection. The return section of the suit hose is capped to prevent cabin gas flowing into the suit circuit when crewmen remove their suits.

Cabin gases are returned to the suit circuit for removal of carbon dioxide, odors, heat, and moisture. These gases enter at the suit circuit return air valve assembly, which consists of two check valves in series, and a manual shutoff valve for isolating the suit circuit if the cabin becomes contaminated. The combined cabin and suit circuit atmosphere first flows through the debris trap, where small particles of solid matter are removed. The trap contains a bypass valve in the event the filter screen becomes clogged.

ECS

Two suit compressors, connected in parallel, maintain circulation within the suit circuit. Normally only one compressor is operated at a time; however, both may be operated for a small advantage in sensible heat removal with a large increase in power consumption in all cases except prelaunch, or when the three crewmembers are unsuited in a 5-psia pressurized cabin. A differential pressure transducer between the inlet and outlet manifolds of the compressor supplies signals for indication on the main display console (panel 13). Compressor output is dependent on the mode of operation. In normal space operation, the operating compressor delivers approximately 35 cubic feet per minute of suit gas at a pressure rise of 10 inches of water within the condition of 4.93 psia and 88°F. When the cabin is unpressurized, the operating compressor delivers approximately 34.5 cubic feet per minute suit gas at a pressure rise of 6.9 inches of water when inlet conditions are 3.51 psia at 85°F.

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The suit demand pressure regulator (figure 2.7-2) controls suit circuit pressure in normal and emergency modes. It supplies oxygen to the suits whenever the suit circuit is isolated from the cabin, and during depressurized operations. It also relieves excess gas to prevent over-pressurizing the suits.

The regulator consists essentially of two redundant demand regulators, and a relief valve. A selector valve is provided for selecting either or both regulators. Normally both are in operation.

Each regulator section consists of an aneroid control, and a differential diaphragm housed in a reference chamber. The diaphragm is connected by a rod to the demand valve. The demand valve will be opened whenever a pressure differential is sensed across the diaphragm. In operation there is a constant bleed flow of oxygen from the supply into the reference chamber,

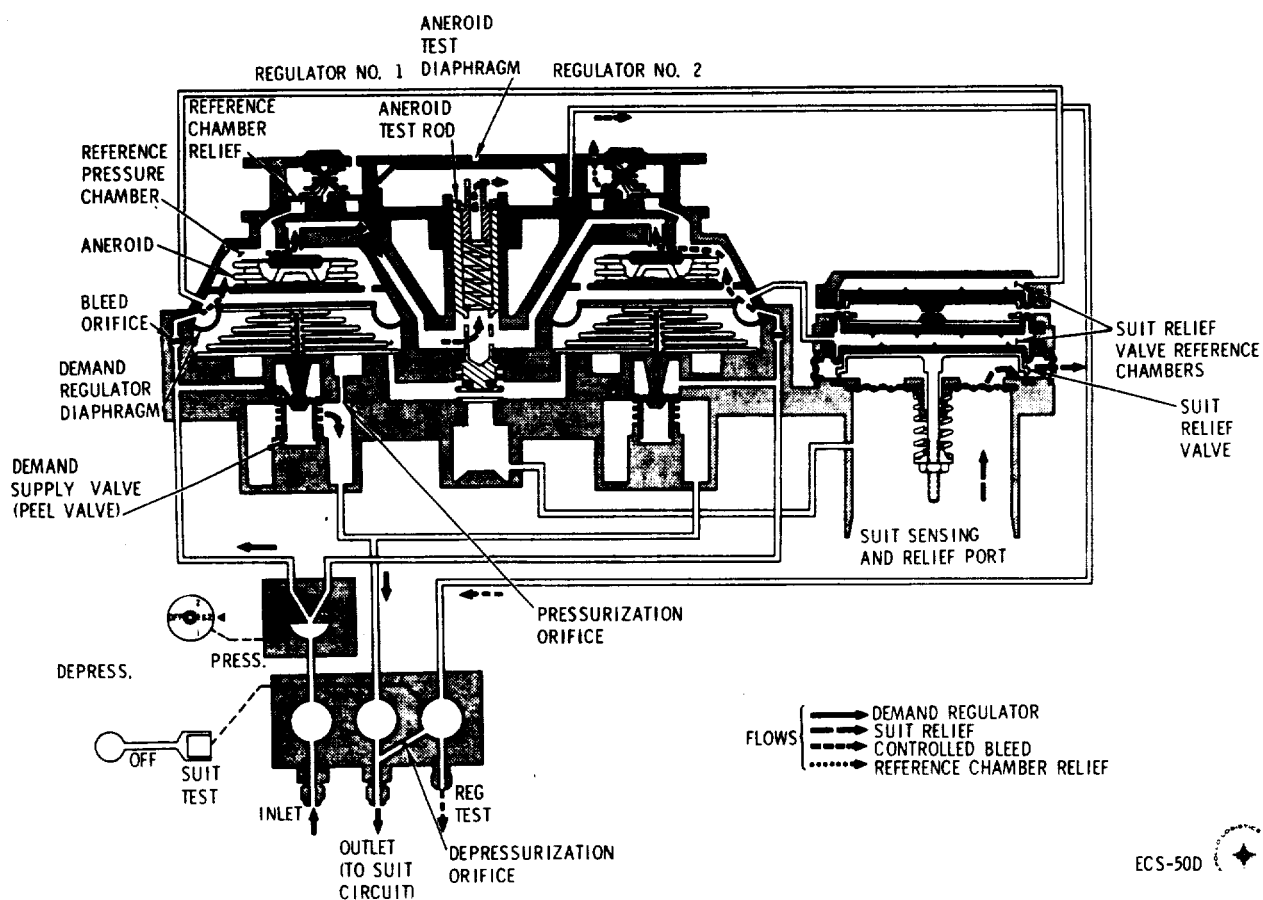


Figure 2.7-2. Oxygen Demand Pressure Regulator and Relief Valve



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around the aneroid, and out through the control port into the cabin. As long as the cabin pressure is greater than 3.75 psia, the flow of oxygen through the control port is virtually unrestricted, so that the pressure within the reference chamber is essentially that of the cabin. This pressure acts on the upper side of the diaphragm, while suit pressure is applied to the underside. The diaphragm can be made to open the demand valve by either increasing the reference chamber pressure, or by decreasing the sensed suit pressure.

The increased pressure mode occurs during depressurized operations. As the cabin pressure decreases the aneroid expands. At 3.75 psia the aneroid will have expanded sufficiently to restrict the outflow of oxygen through the control port, thus increasing the reference chamber pressure.

Decreased suit pressure mode occurs whenever the suit circuit is isolated from the cabin, and cabin pressure is above 5 psia. In the process of respiration the crew will exhale carbon dioxide and water vapor. In circulating the suit gases through the CO<sub>2</sub>-odor absorber and the suit heat exchanger, the CO<sub>2</sub> and water are removed. The removal reduces the pressure in the suit circuit, which is sensed by the regulator on the underside of the diaphragm. When the pressure drops approximately 2 inches H<sub>2</sub>O below cabin pressure, the diaphragm will open the demand valve.

The regulator assembly contains a poppet-type relief valve which is integral with the suit pressure sense port. During operations when the cabin pressure is above 3.75 psia, the relief valve is loaded by a coil spring which allows excess suit gas to be vented whenever suit pressure rises 2 to 9 inches H<sub>2</sub>O above cabin pressure. When the cabin pressure decreases to 3.75 psia, the reference chamber pressure is increased by the throttling effect of the expanding aneroid. The reference chamber pressure is applied through ducts to two relief-valve loading chambers which are arranged in tandem above the relief valve poppet. The pressure in the loading chambers acts on tandem diaphragms which are forced against the relief valve poppet. The relief portion of the valve is thus increased to 3.75 psia plus 2 to 9 inches H<sub>2</sub>O.

ECS

Two parallel CO<sub>2</sub>-odor absorber canisters, downstream of the suit compressors, function in the removal of carbon dioxide and odors. A removable filter within each canister contains sufficient lithium hydroxide (for CO<sub>2</sub> removal) and activated charcoal (for odor removal) to last 1.5 man-days of operation. This operational limit requires each filter be changed, on an alternating basis, every 12 hours. An internal bypass is incorporated within each filter to furnish the required flow during the ECS emergency mode (cabin depressurized), but will also increase the flow under normal conditions. Although 50 percent of the flow is permitted to bypass the lithium hydroxide, the total flow must pass through the charcoal filter.

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The CO<sub>2</sub>-odor absorber filter change sequence involves numerically identified filters and alphabetically identified filter stowage containers. Although the filters are replaced in numerical sequence, the stowage containers are not opened in alphabetical sequence relative to filter replacement. Odd-numbered filters will always be installed in suit circuit canister A (upper) and even-numbered filters installed in canister B (lower). After the proper filter stowage container is located by the crewman, the correct filter is obtained and the filter change accomplished. The used filter is then stowed in the container from which the unused replacement came. Where two filters are stowed one above the other, the used filter will always be placed below the remaining unused filter. This provides a more readily accessible unused filter at the next 12-hour replacement period. Filter replacement data, such as filter number and mission time, is recorded by the crew in the flight log.

A diverter valve located at the canisters inlet is normally positioned to direct gas flow through both filters. In conjunction with check valves, located at each canister outlet, repositioning the diverter valve isolates an expended filter. A manually operated vent valve for each canister allows equalization to cabin pressure prior to the removal of a filter.

Suit circuit gases, upon leaving the CO<sub>2</sub>-odor absorber canister assembly, are at a higher temperature and humidity level than at any other point in the suit circuit. Heat has been generated in flowing through the compressors and the canister assembly. Also, the already humid gases have picked up additional moisture due to chemical reaction between the carbon dioxide and lithium hydroxide. The suit heat exchanger removes this heat and humidity from the suit gases.

Normally the heat transfer fluid, water-glycol, flowing through the suit heat exchanger removes the suit circuit heat loads to space through space radiators. A water-glycol evaporator supplements heat transfer when the space radiators are inadequate. A suit evaporator (part of the suit heat exchanger) is provided and used only in the event of an emergency. Under all other conditions the suit evaporator controls are to remain in the OFF position. The control switch (SUIT EVAP, AUTO - MAN, located on panel 13) controls electrical power to the system. This operational change will not impose added constraints on the mission; however, if the water-glycol evaporator should fail when it is required for cooling of electronics, etc., this would be sufficient cause to terminate the mission.

Should the ability of the suit evaporator system demonstrate proper operation, the control switch would be placed to the AUTO position. When water-glycol inlet temperatures to the suit heat exchanger exceed 52°F or the outlet temperatures of the suit circuit gases from the heat exchanger exceed 60°F, the suit heat exchanger is bypassed by the water-glycol flow through a diverter valve. When the automatic-controlled diverter valve is in the full bypass position, an integral switch in the diverter valve assembly is activated. The diverter valve switch activates the suit evaporator steam pressure control unit. The correct steam duct pressure is automatically

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established for a given temperature error by the steam pressure control unit, pressure transducer, and the steam pressure control valve. Initial opening of the steam pressure control valve causes a switch in that valve assembly to activate the wetness control unit. Water inlet through a solenoid valve to the suit evaporator is automatically controlled by sensing the suit evaporator wetness and the temperature of the suit gases at the heat exchanger outlet. When suit gas temperatures return to normal, the evaporator mode is sequentially deactivated and water-glycol flow is re-established. By overriding the suit gases temperature sensor at the outlet of the heat exchanger the system may also be activated, providing the SUIT EVAP control switch is in the AUTO position. Simulated high heat load is initiated by the SUIT HT EXCH switch (LHEB -310).

As the moisture-laden suit gases are cooled, condensation takes place within the heat exchanger. This moisture is absorbed by a wick-like material, removed by capillary action and the suction of the H<sub>2</sub>O accumulator, and pumped into the waste water system.

The two accumulators are automatically controlled, self-cycling, reciprocating pumps. Oxygen at 100±10 psig periodically activates the pumps on the expulsion stroke, while a return spring is utilized for the suction stroke. Only one accumulator can be operated at a time with the second for standby use in the event of a malfunction. A manual backup mode of accumulator operation is also incorporated. Following the discharge of suit circuit gases from the suit heat exchanger, the normal flow is to the three suit hose connector assemblies. A suit flow relief valve is incorporated in the bypass line between the outlet of the suit heat exchanger and the inlet to the suit compressor. The valve opens at a  $\Delta P$  of 5.0±0.2 in. H<sub>2</sub>O and automatically maintains a nearly constant flow in the event of suit circuit flow resistance fluctuations.

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2.7.3.2.1 CO<sub>2</sub> Sensor.

The CO<sub>2</sub> sensor, situated between the inlet and outlet manifolds of the suit circuit, is a compact unit that operates on the infrared absorption principle. The unit measures the amount of infrared energy absorbed by the CO<sub>2</sub> in the atmospheric sample passing through the sensor. This is accomplished by comparing two different wavelengths in the infrared spectrum. One wavelength is absorbed by CO<sub>2</sub>, while the other acts as a reference. This establishes a ratio signal which is amplified and reads out as a d-c voltage proportional to the partial pressure of CO<sub>2</sub> in the sample gas.

The sensor is divided into the optics section and the electronics section. The optics section includes an infrared energy source (a small tungsten filament lamp), and optical lenses and mirror for focusing the beam through two wavelength filters and the atmospheric sample onto a detector. Both wavelength filters (4.3 microns for sampling and 4.0 microns for reference) are attached to a tuning fork which vibrates at

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600 cycles per second. The filters move back and forth across the focused light beam, alternately transmitting energy at the sample and reference wavelengths.

The basic purpose of the electronics section is to detect and transform signal information. Miniaturized components are mounted on seven printed circuit boards, which accomplish all the electrical functions. These functions include supplying the power for the infrared source lamp and the operation of the tuning fork, the detector, and the various preamplifiers and amplifiers. The output signal activates the CO<sub>2</sub> PP HI systems status light (MDC-11) and the CO<sub>2</sub> PART PRESS indicator (MDC-13).

2.7.3.2.2 Gas Chromatograph.

The gas chromatograph is an item of GFE that is installed in several of the Apollo Block I spacecraft for flight qualification purposes. The unit is capable of identifying and measuring the concentrations of 28 gas components, and the resulting data is then telemetered to MSFN. This compact item of equipment is installed in the LEB, and it interfaces the inlet and outlet manifolds of the suit circuit in the LHEB.

The gas chromatograph operates on the basic principle of routing samples of the suit circuit and/or cabin atmosphere through three separate capillary columns and detectors. Low-pressure helium is used as the carrier gas for the sample streams. The helium supply, even under continuous demand, will last the length of any proposed mission. The helium is stored in a reservoir at 6000 psig and is regulated to its normal working pressure of 42 psia. In the event of regulator malfunction, pressure relief is provided by a 200-psig rupture disc. Each capillary column and detector identifies a specific number of gas components. One column-detector will identify five of the permanent gases; namely, hydrogen, nitrogen, oxygen, methane, and carbon monoxide. Another is concerned only with the separation and detection of ammonia, carbon dioxide, and water. The third column-detector identifies 20 trace contaminants listed as follows: Freon II, methyl alcohol, methylene chloride, ethyl alcohol, benzene, P-dioxane, acetone, hydrochloric acid, hydrogen sulfide, ethylene oxide, isoprene, diethyl sulphide, nitrogen dioxide, ethylene glycol, vinylidene chloride, methyl chloroform, acetylene, dimethyl sulfide, Freon 114, and 1, 1 trichloroethane.

Cross-section ionization-type detectors are used in conjunction with the three columns for gas component identification. The output current of the detectors produces a minimum-strength signal that must be greatly amplified, then conditioned for telemetry. The capillary columns, the detectors, and the electrometer amplifiers are housed in an oven, the temperature of which is maintained within a very close tolerance. The balance of the electronics, installed in a separate package, consist of a transformer, a programmer, and a regulated power supply. Solid-state circuitry is used exclusively throughout the electronics of the unit.

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The gas chromatograph will complete one identification cycle in approximately 80 minutes, regardless of the sampling mode selected. Samples are taken from the suit circuit atmosphere, the cabin atmosphere, or from each atmosphere on alternating cycles depending on the positioning of a selector switch located on the LEB panel 120. The selector switch may be positioned to CABIN AIR/AUTO/SUIT AIR by command.

The gas chromatograph is serviced and installed by ground support personnel prior to flight crew ingress.

A three-position START/OFF/PREHEAT switch, controls power for operation, and must be placed to the PREHEAT position for a minimum of 80 minutes before switch is set to START. A push-type switch, AMPL-CAL, for bench calibration only and the START/OFF/PREHEAT switch, are located on panel 120.

During the mission, the flight crew will not be required to make control adjustments to the unit unless directed to do so by MSFN. During descent, the remaining helium in the reservoir is dumped into the cabin by the action of a pyro valve inside the unit. A full tank (abort condition) can be emptied in a maximum of 3 minutes. Pyro valve initiation is simultaneous with the C/M-RCS propellant purge operation.

2.7.3.3 Cabin Pressure and Temperature Control Subsystem.

The pressurization and temperature control of the C/M cabin are primarily automatic functions with manual backup and override modes provided. Cabin pressurization is maintained by the cabin pressure regulator assembly (figure 2.7-3). This unit consists of dual regulators and a manual repressurization valve operated by a knurled knob. Both regulators operate simultaneously as there is no selector valve incorporated and no off position. The regulators automatically maintain the cabin at  $5 \pm 0.2$  psia during normal conditions and at a maximum oxygen flow rate of 1.3 pounds per hour. If the cabin should become depressurized for any reason, the regulators close at a pressure of 3.5 psia to conserve oxygen. The manual valve, with a maximum flow rate of 7.2 pounds per hour, may be adjusted to maintain cabin pressure in event of regulator malfunction. However, it is primarily used to repressurize the cabin following decompression, requiring approximately 1 hour to raise the cabin pressure back to  $5.0 \pm 0.2$  psia.

An emergency cabin pressure regulator assembly (figure 2.7-4) will flood the cabin with oxygen to prevent rapid decompression in the event of cabin wall puncture. As cabin decompression is hazardous to life only when a crewman is in the shirtsleeve mode, the regulators are not selected for use until just prior to a crewman removing his PGA. The regulator

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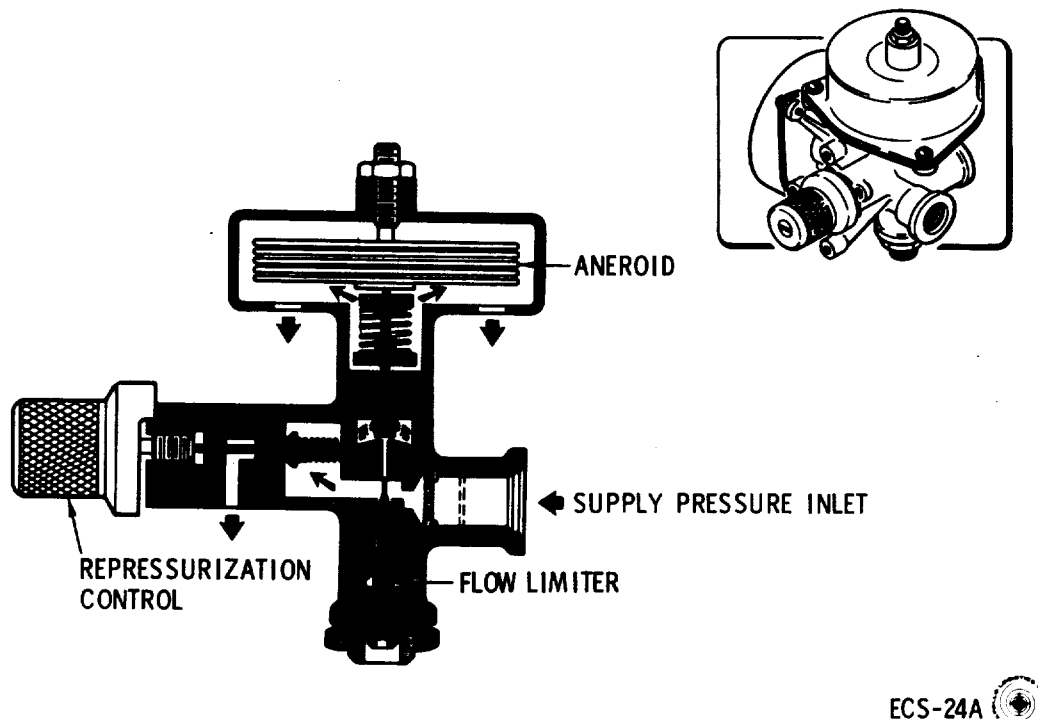


Figure 2.7-3. Cabin Pressure Regulator

assembly consists of a four-position manual selector valve and two redundant regulators which, when selected for use, automatically open when the cabin pressure drops to  $4.5 \pm 0.1$  psia. The emergency cabin pressure mode of 3.5 psia is contingent upon Apollo design limits and meteorite tests and allows unsuited crewmen time to don their PGAs. This minimum pressure can be maintained for 5 minutes, providing that meteorite holes do not exceed the total equivalent area of a hole 0.5 inch in diameter. At the end of this time, the pressure will drop more rapidly, going to 2.0 psia in 10 minutes and to 1.0 psia in 15 minutes.

The dual cabin pressure relief valve (figure 2.7-5) provides positive and negative pressure relief for the cabin throughout the entire mission. Although they function automatically, cable-operated manual override controls, located on panel 307, are provided for adjustments during flight to close relief valves for a malfunction, or to prevent sea water inflow during postlanding phase and ground checkout procedures. When the cabin pressure becomes higher than the external ambient pressure, the relief valves limit the differential pressure to 6 (+0.2, -0.4) psi. During the ascent phase, this differential pressure may go as high as 7.0 psi for a short period of time. Conversely, when the cabin pressure becomes lower than the external ambient pressure (as during descent), the relief valves limit the differential pressure to a maximum of 25 inches of water. The assembly is located in the steam duct overboard line which provides the means of venting the positive and negative cabin pressures.

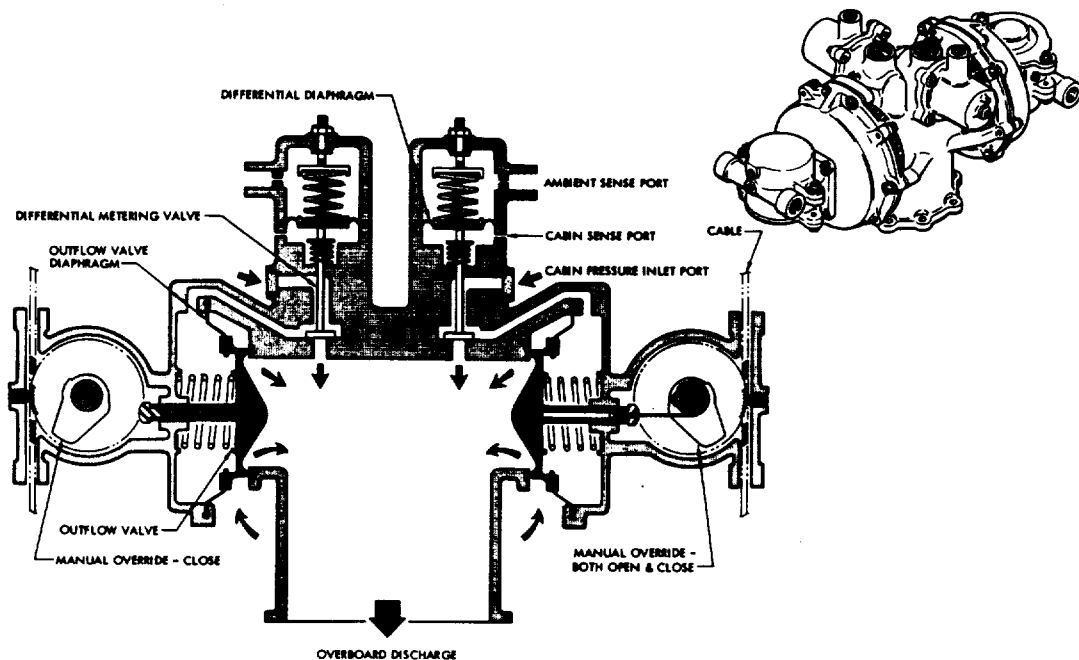
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Although cabin temperature control is normally an automatic function, resort to manual backup and override modes of operation may be utilized. Cabin gases are heated or cooled by their circulation through the cabin heat exchanger, which uses water-glycol as the heat transfer medium. A cabin temperature control unit compares a desired temperature, selected by the crew, to the temperature that is sensed at the inlet to the cabin air fans. Any difference results in a signal that repositions the motor-operated cabin temperature control valve. This valve regulates the amount of hot or cold water-glycol flowing into the cabin heat exchanger. At each end of valve full travel, the total hot or cold flow is routed through the heat exchanger; whereas, at intermediate valve positions, the water-glycol flow through the heat exchanger varies. A cabin temperature anticipator, located at the cabin air control louver discharge, senses the temperature rate of change and signals the cabin temperature control unit, preventing overcorrection by the control valve.

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Figure 2.7-5. Cabin Pressure Relief Valve

Ventilation during the postlanding phase is accomplished by circulating outside ambient air through the cabin. All of the equipment necessary to carry out this function (other than controls) is located on the C/M forward tunnel cover. Outside air is drawn into the cabin through an inlet duct containing a shutoff valve and fan. The inlet duct includes a flexible extension for promoting more efficient ventilation. After circulating within the cabin, the air is expelled overboard through an adjacent outlet duct and shutoff valve. Both motor-operated shutoff (vent) valves and the vent fan are controlled by the VENT FAN switch on MDC-25. High- or low-speed fan operation is available, and either switch position will simultaneously activate the fan and open the cabin vent valves. An assembly consisting of a pendulum-type attitude sensing switch and an adjacent override control switch (PLVC) are installed in the LHEB. The pendulum is free to move only in the Z-axis. Should the C/M roll beyond a specified limit or become inverted (stable II condition), the attitude sensing switch activates the cabin vent valves to the closed position to prevent water ingestion. If all efforts to return the C/M to the upright (stable I) condition should fail, the PLVC switch (LHEB-141) is set to OPEN. This overrides the closing action of the attitude sensing switch by opening both cabin vent valves and flooding the forward portion of the C/M. The pressure on the tunnel hatch then becomes equalized, thus allowing its removal for the escape of the crew. The PLVC switch may also be used to open the cabin vent valves if the attitude sensing switch should fail after having closed the valves. In order to prevent the inadvertent opening of the vent valves in flight, two precautions are taken. A lockpin is installed in each vent valve, and the circuit

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breaker applying power to the PLV system is not engaged during flight. Therefore, before the PLV system can be operated, the lockpins must be removed (pulled out approximately 0.5 in.) prior to CSM separation and the applicable circuit breaker engaged after landing.

2.7.3.4 Water-Glycol Coolant Subsystem.

The water-glycol coolant subsystem is a closed loop through which an aqueous ethylene-glycol mixture (water-glycol) is continuously circulated. The mixture ratio by weight consists of 62.5 parts of glycol to 37.5 parts of water. Basically, the subsystem provides a heat transport fluid loop for the cabin atmosphere, the suit circuit atmosphere, the electronic equipment, and a portion of the potable water. It also serves as a source of heat for the cabin atmosphere when required. All of the unwanted heat absorbed by the water-glycol is transported either to the space radiators, where it is radiated to space, or to the water-glycol evaporator, where it is rejected by the evaporation of water.

The water-glycol (W/G) evaporator outlet temperature must be maintained between 40° and 43°F (nominal 41.5°F). Sensed at the W/G evaporator inlet from the space radiators W/G temperatures between 42.9° and 45.9°F (nominal 45°F) activates the automatic mixing valve control system (figure 2.7-6). High-temperature W/G from the water-glycol pump is mixed with the lower W/G temperature from the space radiators to maintain the evaporator outlet nominal temperature of 41.5°F. The manual override for the mixing valve is located on the coolant control panel 311 (GLYCOL EVAP TEMP IN) and a switch located on panel 13 allows selection of AUTO or MAN operation.

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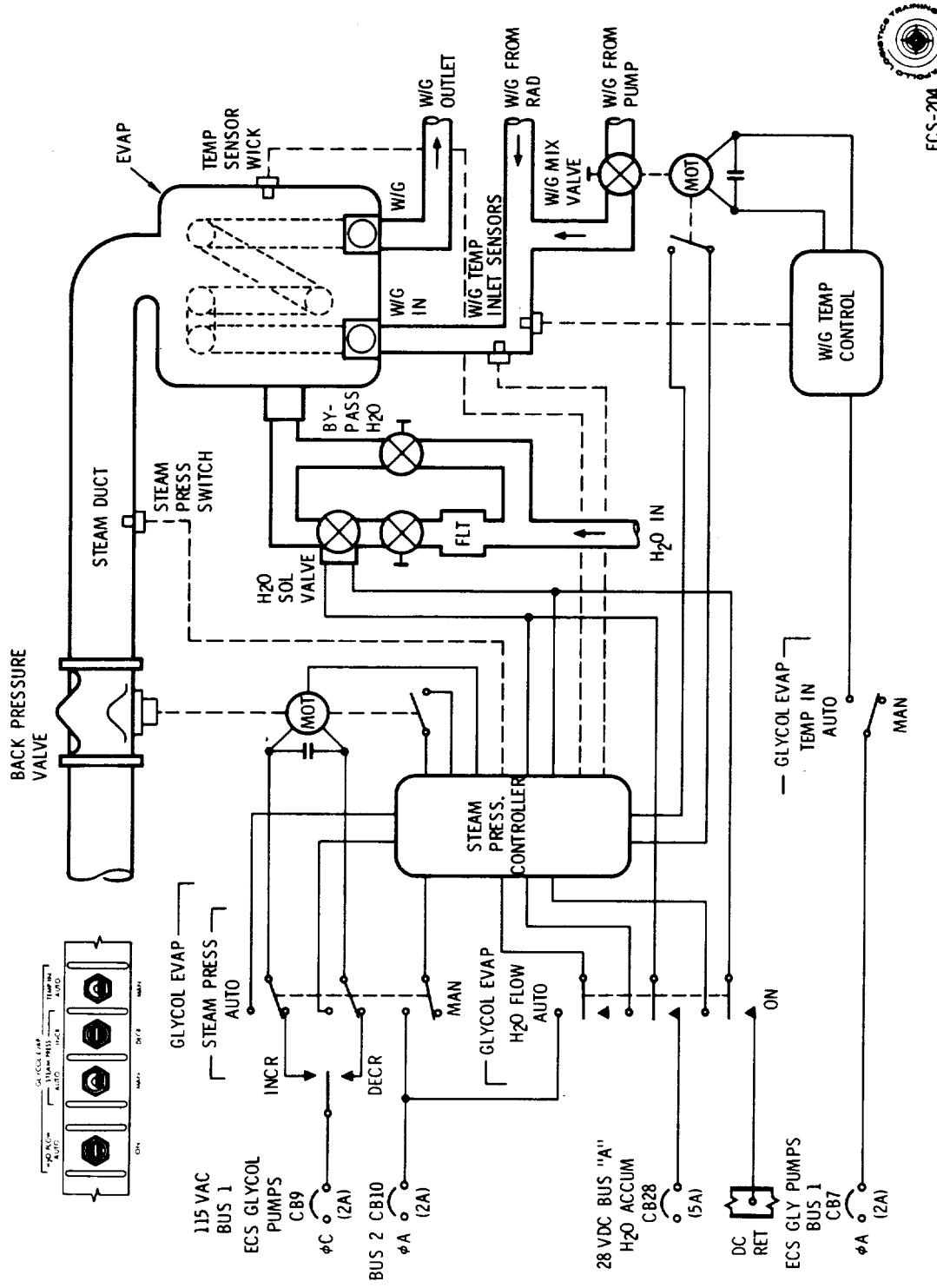
Three lines from the water-glycol pump assembly are paralleled to the water-glycol evaporator inlet. The aforementioned oxygen supply capillary restrictors are wound around the line routed to the space radiators and relief valves. The other line is routed to the mixing valve. To insure proper operation of the oxygen supply restrictors, in the line between the cryogenic O<sub>2</sub> storage in the S/M to the surge tanks in the C/M during cabin repressurization, full water-glycol flow through the line to the space radiators is required. Sufficient heat must be available to prevent cryogenic oxygen entering the C/M oxygen system and preclude the possibility of freezing the water-glycol. To achieve this, the mixing valve must be manually placed to the full closed position 15 to 30 minutes before repressurization and remain closed until the surge tank returns to maximum pressure after repressurization of the C/M.

High-temperature water-glycol between 48° and 50.5°F from the space radiators and sensed at the evaporator inlet initiates the water-glycol evaporator temperature control system. Once the evaporator mode is initiated by the evaporator inlet sensor, an evaporator outlet sensor supplies the controlled variable signals to the controller. If a heating temperature error is sensed by the evaporator outlet sensor, the steam pressure valve begins to open and repositions at a velocity proportional to

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Figure 2.7-6. Water-Glycol Evaporator Temperature Control

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the temperature error. Evaporator wicks are maintained in a wet condition to provide immediate boiling when the steam pressure valve is opened. Should the steam pressure drop below  $5.0 \pm 0.2$  mm Hg abs, a pressure switch overrides the temperature signal and closes the steam pressure valve. The override pressure switch provides adequate pressure margin above the freezing pressure of 4.58 mm Hg abs. A switch in the steam pressure valve assembly is activated when the valve is initially cracked open. The switch activates the wetness control for replenishing water to the evaporator through a water-solenoid control valve. Signals from the wick temperature sensor are indicative of the relative wetness of the evaporator wicks. As water evaporates, the wick sensor temperature increases and exceeds an evaporator inlet reference sensor signal and cycles the water control valve open. The reference input sensor varies the control as a function of heat load to maintain the desired wick temperature with no water carryover into the steam duct. When the evaporator wicks become replenished with water, the wick sensor temperature decreases and approaches the saturation temperature corresponding to the steam pressure and cycles the water control valve closed. The water control valve continues to cycle as long as water-glycol cooling by water evaporation is required.

The steam pressure control valve can be electrically repositioned to control the steam pressure for 40° to 43°F outlet glycol temperature using the pressure monitor indicator (panel 13, GLY EVAP-OUTLET TEMP). The control switches (GLYCOL EVAP - STEAM PRESS) must be placed to the MAN position, and then to INCR for open and DECR for closing the steam pressure valve. The H<sub>2</sub>O FLOW switch (panel 13) should be in the AUTO position for the automatic wetness control to be effective. Should the wetness control fail, the water inlet control valve can be energized open by placing the H<sub>2</sub>O FLOW switch to ON. When operating in this mode, a portable indicating unit should be used to prevent water carryover into the steam duct. The portable indicating unit consists of a four-position selector switch for selecting OFF, WICK TEMP., EVAP INLET TEMP. AND NUL. The unit has its own 175-hour battery-operated power supply. WICK TEMPERATURE indicator markings are 40° to 70°F, WATER-GLYCOL INLET TEMPERATURE indicator markings are 40° to 100°F, and the NUL indicator markings are a red line across the midlength section of the dial face and is marked above the red line on the dial WATER ON, and below on dial WATER OFF. A water control tabulation chart (figure 2.7-7) for operation of W/G evaporator in the manual mode, is provided showing wick temperature versus inlet glycol temperature. The portable indication unit should also be used when manual water bypass control valve (GLY EVAP WATER CONTROL BYPASS panel 317) is used. The portable indicator unit will connect to J39 (panel 311). The main water-glycol flow next enters the cabin temperature control valve, where it is routed either to the cabin heat exchanger or to the remaining thermal coldplates. The action is dependent upon the temperature control unit, which automatically controls the movements of the motor-operated cabin temperature control valve. The valve is so constructed that in the cabin full cooling mode, the total flow of cool water-glycol (167 pounds per hour) is routed first through the cabin

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Evaporator Inlet Temperature Sensor (°F)	Wick Temperature Sensor (°F)	Evaporator Inlet Temperature Sensor (°F)	Wick Temperature Sensor (°F)
40	41.62	71	54.63
41	42.13	72	54.96
42	42.65	73	55.28
43	43.15	74	55.60
44	43.65	75	55.91
45	44.14	76	56.21
46	44.63	77	56.51
47	45.11	78	56.80
48	45.58	79	57.08
49	46.04	80	57.37
50	46.50	81	57.66
51	46.95	82	57.93
52	47.39	83	58.19
53	47.82	84	58.46
54	48.25	85	58.71
55	48.67	86	58.96
56	49.08	87	59.21
57	49.49	88	59.46
58	49.89	89	59.71
59	50.30	90	59.94
60	50.39	91	60.17
61	51.07	92	60.40
62	51.45	93	60.63
63	51.83	94	60.85
64	52.20	95	61.06
65	52.56	96	61.28
66	52.92	97	61.49
67	53.27	98	61.69
68	53.62	99	61.90
69	53.96	100	62.10
70	54.30		

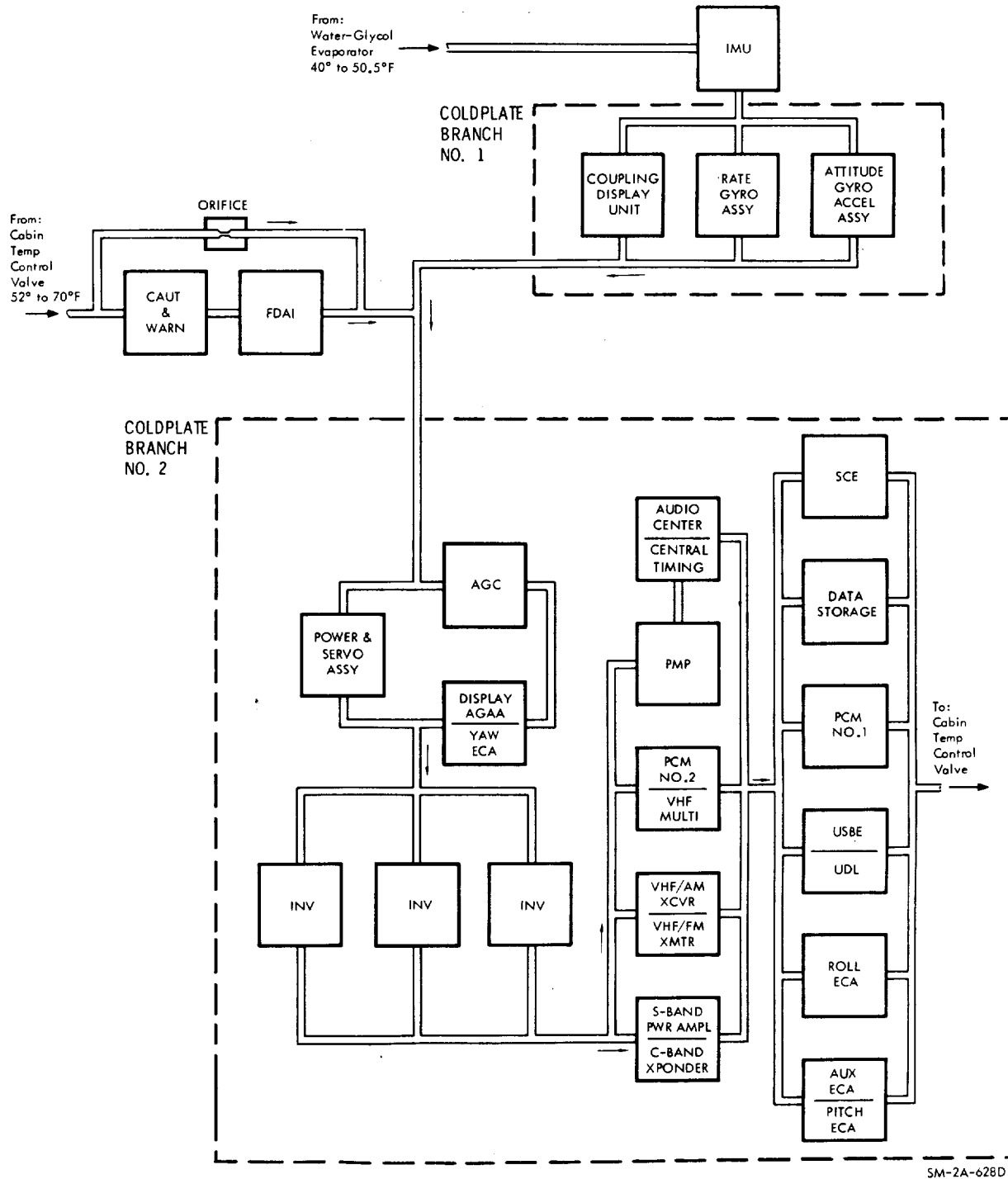
Figure 2.7-7. Water Flow Control Chart

heat exchanger and then through the thermal coldplates. In the cabin full heating mode, the total flow is routed through the thermal coldplates first, where the water-glycol absorbs heat, and from there flows through the cabin heat exchanger. The intermediate valve positions are for the partial cooling or partial heating modes. In the intermediate positions, the quantity of cool or warm water-glycol flowing through the heat exchanger is reduced in proportion to the demand for cooling or heating. Although the amount of water-glycol flowing through the cabin heat exchanger will vary, the total flow through the thermal coldplates will always be 200 pounds per hour. (See figure 2.7-8.) An orifice restrictor is installed between the cabin temperature control valve and the inlet to the coldplates. Its purpose is to maintain a constant flow rate through the coldplates by reducing the

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Figure 2.7-8. Equipment Coldplate Flow Diagram

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heating mode flow rate to that of the cooling mode flow rate. Another orifice restrictor, located in the coolant line from the IMU, maintains a constant flow rate through this component regardless of system flow fluctuations.

The total flow leaving the cabin temperature control valve enters the water-glycol pump assembly which provides the continuous coolant circulation within the subsystem. The assembly consists of two water-glycol pumps, two pump outlet check valves, a full-flow filter, an accumulator, and an accumulator isolation shutoff valve. The two pumps, mounted in parallel, can only be operated one at a time with the second pump for standby redundancy. Each pump outlet check valve prevents coolant back-flow through the nonoperating pump. Water-glycol entering the assembly first passes through the full-flow filter before reaching the pumps. There is also a side passage that leads to the accumulator.

The purpose of the accumulator is to maintain correct pump inlet pressure and to compensate for small amounts of leakage and/or thermal expansion/contraction. The manual shutoff valve in the side passage is closed to isolate the accumulator in case of a punctured bellows, which would permit the coolant to leak into the cabin, causing contamination. If the water-glycol accumulator quantity indicator on the main display console shows a steady decay to zero, a leak in the water-glycol system is the probable cause. However, an indication showing a slow steady decrease, which stops at a point above zero, is probably due to thermal contraction indicating the water-glycol temperature is below the nominal range. Located downstream of the pump assembly is the water-glycol pump outlet pressure transducer which measures the static pressure of the water-glycol at the pump outlet, thus giving an indication of pump performance.

At this point in the subsystem, the temperature of the water-glycol has greatly increased due to the absorption of the various heat loads. The total flow of hot water-glycol is routed through a passage in the steam pressure control valve to prevent ice from forming within the valve opening. Icing at this location could result in valve malfunction and/or blocking of the steam duct. To prevent ice from forming at the outlet of the steam duct, two redundant electric heaters are used. The two 3-watt heater elements inside the duct extend approximately 8 inches upstream from the outlet.

The water-glycol next flows to the water-glycol evaporator inlet temperature control valve (previously described). The hot water-glycol that is not used for mixing by this valve is routed to the space radiators for cooling. Any pressure losses in the space radiator circuit, regardless of the number of radiators in operation, will be limited by the action of the dual water-glycol pressure relief valves. These two valves are in parallel and are located between the inlet and outlet lines of the radiator circuit. Just upstream of each pressure relief valve is a manual shutoff valve. By controlling the shutoff valves, one relief valve at a time is normally selected for use with the second for standby redundancy. When a  $\Delta P$  of

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11 psi is reached, the relief valves open to bypass coolant to the radiator return line, closing at a  $\Delta P$  of 8.5 psi. In order to preserve the water-glycol closed loop, the relief valves function as a bypass when all space radiator isolation valves are closed or when the water-glycol radiator shut-off valve is closed. This is a manual shutoff valve that controls the flow of water-glycol from the C/M to the S/M. It is placed to the closed position shortly before CSM separation to prevent the coolant in the C/M from flowing overboard after separation.

Two space radiators with an area of 30 square feet each are located on opposite sides of the S/M in sectors II and V. Each radiator panel contains two separate sets of tubes. The flow of water-glycol through the four tube circuits is individually regulated by a motor-operated radiator isolation valve located on the inlet side of each tube circuit. The four valves are remotely controlled from the C/M and give the crew some degree of latitude in their selection of cooling area. However, the primary purpose of the valves is to isolate tube circuits should they develop leaks. A check valve in each tube circuit outlet line prevents the backflow of coolant from entering any radiator tube circuit that is leaking. Freezing within the radiators is the point at which flow ceases, and may be prevented by maintaining the inlet temperature above 75°F. This temperature is obtained on the AUX DC VOLTS meter (RHFEB-200) or from MSFN if the crew is unable to leave the couches.

The water-glycol, after leaving the space radiators and re-entering the C/M, flows through a capillary restrictor. This is placed in the line to make the pressure drop through the radiators compatible with that through the water-glycol temperature control valve during the mixing mode. Upon leaving the restrictor, the water-glycol flows through two check valves in series. These valves prevent coolant from flowing overboard following CSM separation. A temperature sensor, located between these check valves, gives an indication on the main display console of the temperature of the coolant leaving the radiators. The indicator is located on MDC-13.

Under normal space flight conditions the water-glycol reservoir is isolated from the coolant subsystem by the proper positioning of three glycol reservoir manual shutoff valves. The water-glycol reservoir inlet and outlet valves are closed, and the reservoir bypass valve between the inlet and outlet lines is opened. During the prelaunch and ascent phases, however, the position of these three valves is reversed to permit coolant flow through the reservoir. The one gallon of water-glycol contained in the reservoir is then utilized as a heat sink, which becomes necessary during the ascent phase. The space radiators are not effective during ascent and evaporative cooling takes place only after the ambient pressure reaches 0.05 psia, which is approximately 150,000 feet altitude (T + 2 minutes and 10 seconds).

If a water-glycol leak should occur, the coolant subsystem may be refilled from the limited supply in the water-glycol reservoir after the leak is isolated. The glycol reserve shutoff valve, located in the line from

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the reservoir to the inlet side of the pump, is used for this purpose. As the reservoir contains a bladder that is under  $20 \pm 2$  psig oxygen pressure, positive expulsion of the coolant is assured. The pressurized reservoir may also serve as an accumulator for the coolant subsystem, if the regular water-glycol accumulator becomes inoperative and is isolated. The flow of water-glycol, either through the reservoir or bypassing it, next enters the water-glycol evaporator (previously described), thus completing the coolant loop.

During prelaunch operations, the flow of temperature-controlled water-glycol is furnished by GSE through lines connected to the fill and vent couplings in the S/M. The solenoid-operated water-glycol shutoff valve, upstream of the outlet coupling, is controlled at the GSE and is opened to permit coolant flow through the spacecraft loop and back to the GSE.

2.7.3.5 Water Supply Subsystem.

The primary function of the water supply subsystem is the storage and collection of potable and waste water. Potable water produced by the fuel cells and waste water recovered from the suit heat exchanger water separator are stored in separate tanks in the C/M. Supplementing this supply are two water tanks in the S/M that contain potable water for refilling the C/M potable water storage tank. The water supply subsystem also supplies hot and cold potable water to the crew and waste water to the water-glycol evaporator and suit heat exchanger for evaporative cooling.

The water produced by the fuel cells in the S/M is a steady source of potable water and is stored in a 36-pound capacity tank located in the aft compartment of the C/M. The tank, which contains a bladder, is pressurized with oxygen at  $20 \pm 2$  psig by the tank pressure regulator and relief valve assembly, thus assuring positive expulsion of fluid. Fuel cell water flows into the tank at a potential pressure of approximately 61.5 psia, which is high enough to overcome the tank pressure. The potable water tank may be serviced before flight by the manually operated servicing valve, which is also in the aft compartment and not accessible to the crew. A quantity indicator on the main display console gives the measurements obtained by the tank quantity transducer. Located in a water line between the fuel cells and the potable water tank is a check valve and the potable tank inlet shutoff valve. The check valve prevents any reverse flow of potable water. The shutoff valve, when closed, prevents fuel cell water that has become contaminated from entering the C/M potable water network.

Temperature-controlled potable water is available to the crew from two components within the C/M. Cold water, which is maintained to  $50^\circ\text{F}$  (at the water chiller), is available at both the food preparation water supply unit and the water delivery unit. Hot water, however, is available only at the food preparation water supply unit. This component utilizes a small tank with an electric heater to raise the water temperature to  $154 \pm 4^\circ\text{F}$ . By selecting the proper valve, hot or cold water is metered out for food reconstitution or other crew needs. The water delivery unit is used by the

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crew exclusively for drinking purposes. It consists of a housing containing a coiled flexible tube and a water delivery valve for use with the individual mouthpieces of the three crewmen. Upstream of this unit is the drinking water supply shutoff valve that is closed if the water delivery valve should leak.

Waste water collected from moisture condensate within the suit heat exchanger is drawn into one of the cyclic accumulators and from there pumped into the waste water network. If, however, there is a water demand by either the water-glycol evaporator or the suit heat exchanger evaporator, the waste water flows directly to the water control valve of the appropriate evaporator. The 56-pound capacity waste water tank contains the pressurization and quantity measuring features of the potable water tank. A servicing valve is located on the water control panel in the C/M cabin and, therefore, is accessible to the crew, if necessary.

Although waste water never enters the potable water network, potable water may enter the waste water network under certain conditions. If the potable tank becomes full, the differential pressure between the networks will eventually overcome the  $6.0 \pm 0.5$  psi at the waste tank inlet valve, thus permitting water flow. Potable water also enters the waste water network if the waste tank is empty and there is a water demand by either evaporator. The low pressure created by this water demand is responsible for waste tank inlet valve activation. The valve also incorporates a manual shutoff feature for use if the relief valve portion malfunctions. Closing the valve thus prevents the premature dumping of potable water into the waste water network. A check valve, located downstream of the relief valve, separates the potable and waste water networks by permitting flow in one direction only.

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To prevent overpressurizing the water supply subsystem, a pressure relief assembly is installed downstream of the check valves that separate the potable and waste water networks. The assembly consists of a selector valve and two redundant pressure relief valves in parallel. When the potable and waste water tanks are full, the continued supply of water produced by the fuel cells will be dumped overboard by these relief valves. Normally, both valves are selected for simultaneous use, and dumping occurs when the water pressure reaches approximately 32 psi above the outside ambient pressure. Another line, with two check valves in series, bypasses fuel cell water output directly to the pressure relief assembly. However, this action will take place only in event the waste tank inlet valve fails closed. The bypass prevents fuel cell water flow from being blocked, thereby preventing total fuel cell failure due to flooding within the cells.

To provide sufficient water for a maximum duration earth orbital mission, two 56-pound water tanks are installed in the S/M. These tanks are similar to the C/M waste water tank but lack the quantity measuring capability. A separate tank pressurizing system is used for positive expulsion of the water. Nitrogen at 900 psig is stored in a small tank that is protected against overpressure by a relief valve set at  $1045 \pm 25$  psig. In

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addition to a nitrogen fill valve, there is a pressure regulator and relief valve to reduce and regulate nitrogen pressure in the water tanks. These tanks are pressurized at  $40 \pm 2$  psig, and the relief valve will function at 44 to 48 psig.

At the water outlet of each tank, there is a manual fill valve and a solenoid shutoff valve. The shutoff valves are controlled by the WASTE H<sub>2</sub>O TK REFILL switch in the C/M. These valves control the flow of water from the tanks to a common line in the S/M that subsequently connects into the potable water line from the fuel cells. When the C/M potable water tank quantity is low, it will be refilled from these S/M water tanks at a flow rate of 2.92 pounds per minute.

2.7.3.6 ECS-Waste Management System Interface.

Although the waste management system (WMS) and C/M battery venting network are not subsystems of the ECS, they will be covered as such in the AOH because of system interface. The interface mentioned is in reference to the ECS water overflow line. All of the urine and the fecal odors of the WMS, as well as gas pressure from the C/M batteries, are also routed overboard through this single ECS water dump line. Incorporated at the outlet of the dump line (urine/water) is a 0.055 inch orifice nozzle that restricts gas flow to a maximum of 1 cfm and liquid flow to less than 1 cfm. The gas flow is limited to prevent excessive loss of cabin atmosphere during fecal canister usage. The restriction on liquid flow, in conjunction with a 5.7-watt, continuously operating dump nozzle heater, prevents the formation of ice at the nozzle, which could block all flow.

The function of controlling and/or disposing of waste solids, liquids, and gases is accomplished by the WMS. Except for the fecal canister and other items of stowed equipment, the major portion of the system is located in the RHEB. The WMS is basically divided into the urine/fecal and the vacuum cleaner subsystems. Several components that are no longer functional have not been removed from the WMS, as shown in figure 2.7-9. This is due to recent modifications that would not permit their removal because of schedule impact.

The components for the urine portion of the urine/fecal subsystem consist of a separate urine sample volume measuring system unit (USVMS) for each crewmember. (Refer to section 5.) The unit is used for each urination in order to provide a urine sample, with the remainder of the contents being dumped overboard in the following manner. The USVMS is first attached by quick-disconnect to an inline filter, which remains attached (by quick-disconnect) to the waste management dump line. The USVMS valve is set to the DUMP position, followed by setting the WASTE MANAGEMENT-SELECTOR valve on RHEB-201 to URINE FECES and the adjacent OVBD DRAIN valve to DUMP. A 5-psi differential pressure, provided by the valve settings, will empty the contents of the collection bag overboard through the urine/water dump line. Should a USVMS unit fail, direct overboard urination may be accomplished by using the urine

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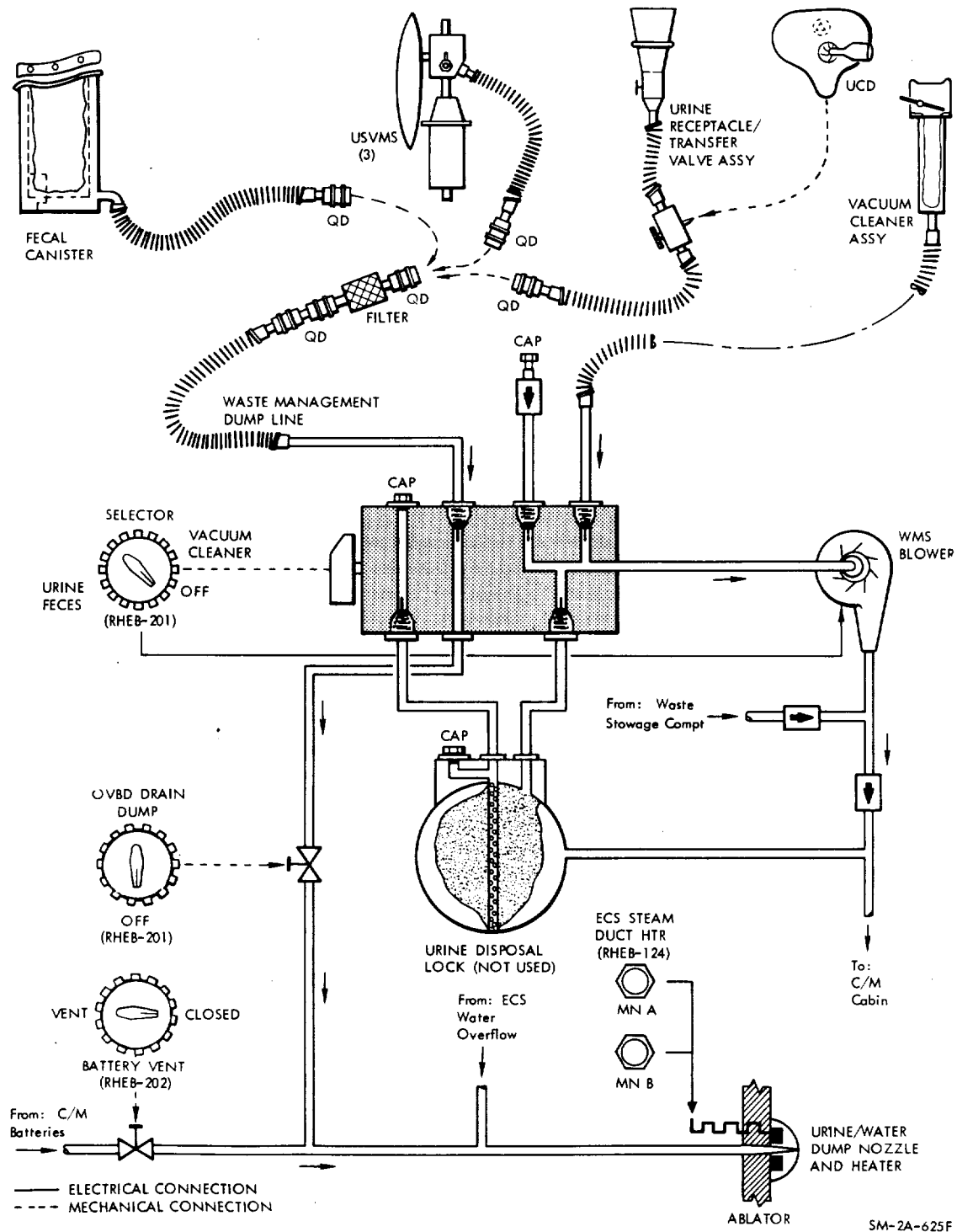


Figure 2.7-9. WMS Functional Flow Diagram

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receptacle, which is a backup component. The PHA urine collection device (UCD) may be used during prelaunch, and if so, is emptied in much the same way. The transfer valve (of the urine receptacle/transfer valve assembly) is inserted into the UCD after it is removed from the PGA. The urine receptacle is then attached by quick-disconnect to the filter on the waste management dump line. The WASTE MANAGEMENT-SELECTOR and OVBD DRAIN valves are set to the URINE FECES and DUMP positions respectively, emptying the contents overboard. Upon completion, the PGA UCD is stowed in the PGA stowage bag. Although the WMS blower will operate whenever the SELECTOR valve is set to the URINE FECES position, functional operation of the blower is for vacuum cleaning only.

For the fecal portion of the urine/fecal subsystem, components consist only of the fecal canister and hose assembly. Normally stowed out of the way, the canister is secured to the center CO<sub>2</sub>-odor absorber filter storage container at the LEB. The hose is then attached by quick-disconnect to the filter on the waste management dump line. The WASTE MANAGEMENT-SELECTOR valve is set to URINE FECES and the OVBD DRAIN valve is set to DUMP. Differential pressure of 5 psi is thus created, routing the odors overboard through the urine/water dump line.

The vacuum cleaner subsystem is made up of the vacuum assembly and an 8-foot flex hose, which are stowed in the vacuum stowage compartment. After removing the vacuum cleaner from the storage compartment, it is placed in operation by setting the WASTE MANAGEMENT-SELECTOR valve to VACUUM CLEANER. This single action activates the WMS blower and opens the valve port that connects the vacuum cleaner line to the blower. The WMS blower provides a gas flow of 5 cfm at a  $\Delta P$  of -4.9 inches H<sub>2</sub>O to effectively remove debris, either solid or liquid. A porous bag, inserted into the vacuum assembly, traps the debris while the gases are exhausted into the C/M cabin.

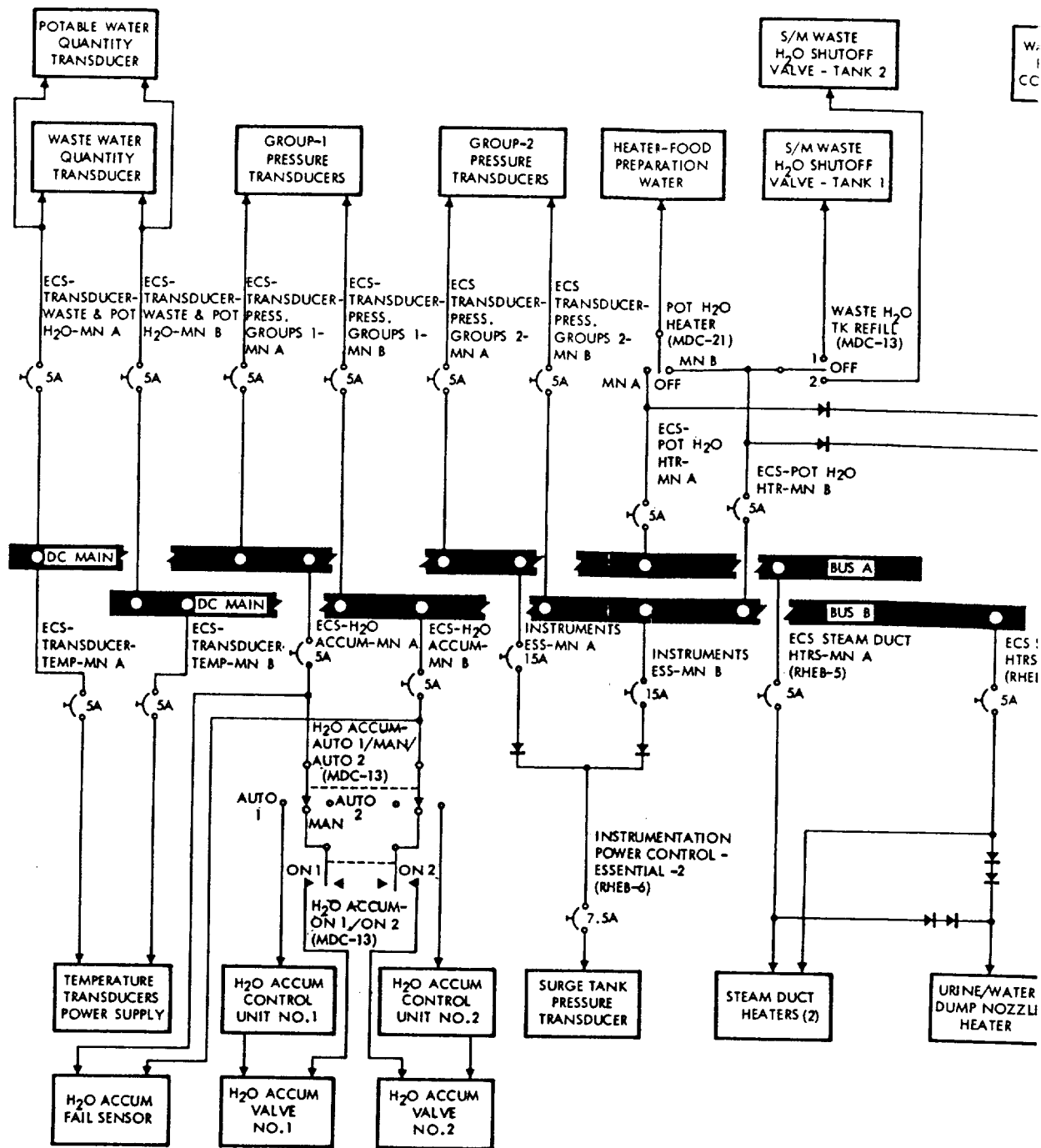
The C/M battery venting network consists of a manifold, a BATTERY VENT valve (RHEB-202), and lines that are routed to connect into the urine/water dump line. The vent valve is to remain in the VENT position during normal operation to provide unrestricted flow for intermittent battery relief valve operation. Only in event of a battery case rupture or vent manifold leakage will the vent valve be closed. This prevents loss of cabin atmosphere overboard, thereby, conserving oxygen.

2.7.3.7 Electrical Power Distribution.

The types of electrical power required for the operation of the ECS are 28 volts dc and 115/200-volts 400-cycles 3-phase ac. (See figure 2.7-10.) The larger motors of the system utilize 200-volt 3-phase power, whereas the smaller motors and control circuits operate from a single phase of the ac at 115 volts. Except for the postlanding ventilation system, those components using 28 volts dc will receive power from the fuel cells before CSM separation and from batteries after separation. The postlanding ventilation system will operate from batteries, exclusively.

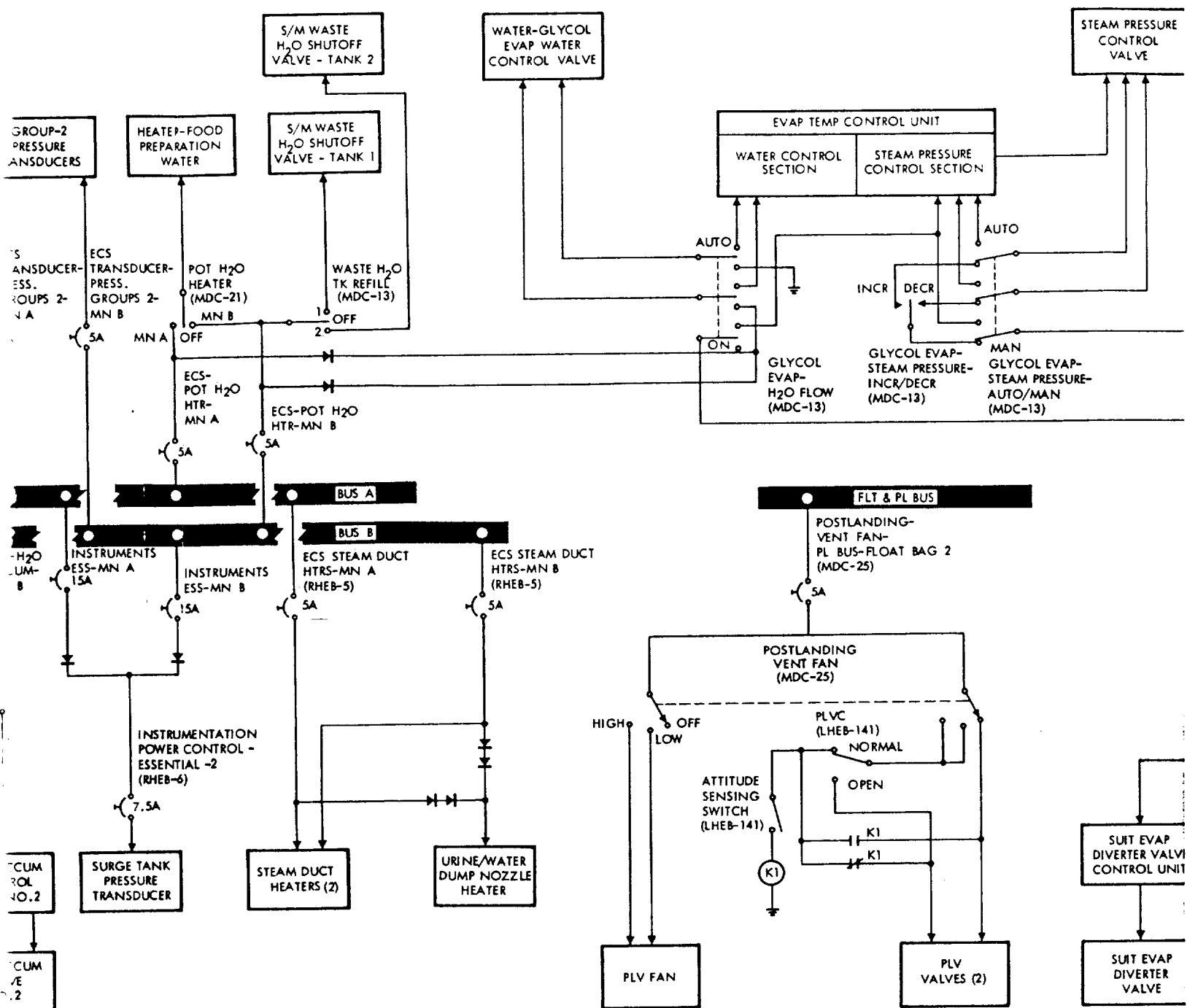
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BOLDOUT FRAME /





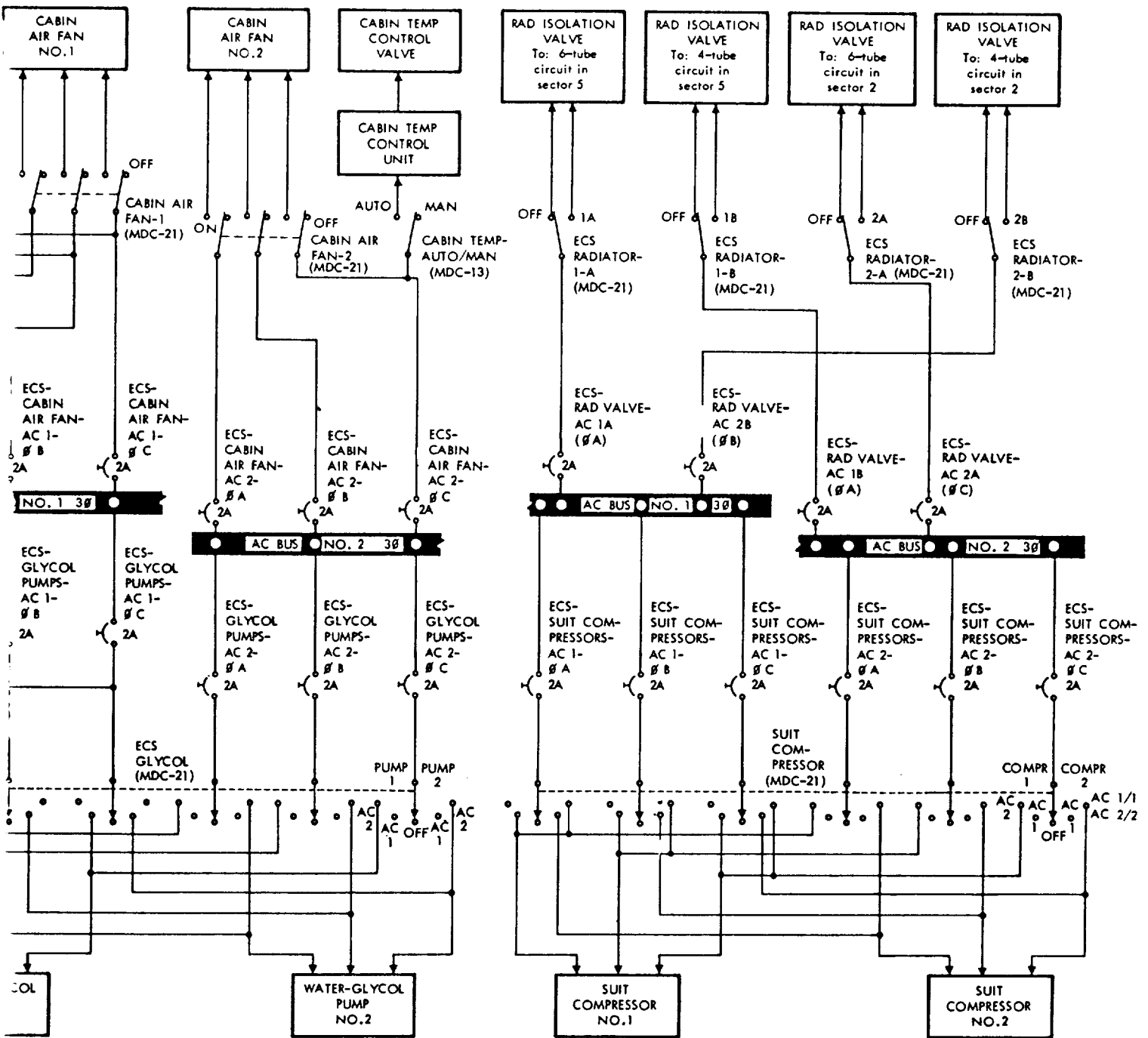








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Figure 2.7-10. ECS Power Distribution Diagram

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KOLDOUT FRAME 4



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2.7.4 PERFORMANCE AND DESIGN DATA.

2.7.4.1 Metabolic Data.

The following table contains the average metabolic rates, thermal balance, and water requirements for S/C crewmembers.

Parameter	Pressurized Cabin (Normal)	Depressurized Cabin (Emergency)
Total metabolic load BTU per man/day	11,200	12,000
Water production lb per man/day	4.0	9.8
CO <sub>2</sub> production lb per man/day	2.12	2.27
O <sub>2</sub> consumption lb per man/day	1.84	1.97
Water consumption lb per man/day	6.6	12.4
Urine production lb per man/day	2.6	2.6

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2.7.4.2 Oxygen Supply Subsystem.

Performance and design data for the oxygen supply subsystem are as follows:

- Maximum oxygen flow rate to ECS from cryogenic storage tanks:  
9.0 lb per hr
- Surge tank quantity: 3.7 lb (approx)  
Surge tank nominal pressure: 900±35 psig  
Surge tank pressure relief setting: 1045±25 psig
- Entry tank quantity: 1 lb (approx)  
Entry tank nominal pressure: 900±35 psig  
Entry tank pressure relief setting: None
- Regulated working oxygen pressure: 100±10 psig  
Pressure relief setting: 130±10 psig  
Flow rate: 0.7 lb per min max
- Regulated tank pressurization oxygen pressure: 20±2 psig  
Pressure relief setting: 25±2 psig  
Flow rate: 0.075 lb per min (one regulator) and 0.15 lb per min  
(two regulators)

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2.7.4.3 Pressure Suit Circuit Subsystem.

Performance and design data for the pressure suit circuit subsystem are as follows:

- Heat exchanger cooling capacity: 2100 BTU per hr max (Gly or evap)
- Water evaporation rate: 1.97 lb per hr max
- Regulated demand pressure  
Normal: 2.5 to 3.5 in. H<sub>2</sub>O below cabin pressure  
Emergency: 3.75 ±0.25 psia  
Flow rate: 0.67 lb per min max
- Suit compressor volumetric flow  
Normal flight: 35 cfm  
Emergency flight: 33.6 cfm
- Automatic temperature control: 45° to 55°F
- Max O<sub>2</sub> flow into suit circuit: 0.66 lb per min (regulator or manual valve)

2.7.4.4 Cabin Pressure and Temperature Control Subsystem.

Performance and design data for the cabin pressure and temperature control subsystem are as follows:

- Heat exchanger cooling capacity: 1250 BTU per hr max
- Regulated cabin pressure: 5.0±0.2 psig  
Flow rate: 0.65 lb per hr (one regulator) and 1.3 lb per hr (two regulators)
- Emergency inflow pressure (maximum of 0.5 in. diameter total leakage area): 3.5 psia for 5 minutes  
Flow rate: 0.67 lb per min max
- Cabin pressure relief  
Positive relief: 6.0 (+0.2, -0.4) psig  
Negative relief: 10 to 25 in. H<sub>2</sub>O
- Differential pressure (C/M cabin-to-aft section)  
Normal ascent: 7.0 psig max.  
Abort ascent: 8.6 psig max.
- Automatic temperature control (flight): 70° to 80°F
- O<sub>2</sub> required for cabin repressurization, 0 to 5 psig at 70°F: 9.1 lb

2.7.4.5 Water-Glycol Coolant Subsystem.

Performance and design data for the water-glycol coolant subsystem are as follows:

- Reservoir quantity: 9 lb (approx)
- Total system quantity (less reservoir): 18 lb (approx)
- Evaporator cooling capacity: 7620 BTU per hr max

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- Water evaporation rate: 7.5 lb per hr max
- Accumulator quantity: 1.36 lb (approx)
- Pump flow: 200 lb per hr
- Pump pressure
  - Inlet:  $7.5 \pm 1.5$  psig
  - Outlet (flight):  $38(+8, -12)$  psia
- Automatic temperature control:  $40^{\circ}$  to  $50.5^{\circ}\text{F}$

2.7.4.6 Water Supply Subsystem.

Performance and design data for the water supply subsystem are as follows:

- Potable tank quantity: 36 lb
- Waste tank quantity: 56 lb
- S/M water tank quantity: 112 lb (2 tanks)
- S/M nitrogen tank quantity (pressurant): capacity of 3.7 lb, filled to 1.5 lb (approx)
- Nitrogen tank fill pressure: 900 psig
- Nitrogen tank pressure relief setting:  $1045 \pm 25$  psig
- Nitrogen system regulated pressure:  $40 \pm 2$  psig
- Nitrogen system pressure relief setting: 44 to 48 psig
- Overboard dump pressure: approx 32 psi above outside ambient  
Flow rate: 2.5 lb per min max
- Food preparation water supply unit
  - Capacity: 1.9 lb
  - Hot water:  $154^{\circ} \pm 4^{\circ}\text{F}$
  - Cold water:  $50^{\circ}\text{F}$  (at water chiller)

ECS

2.7.4.7 Waste Management System.

Performance and design data for the waste management system is as follows:

- Urine/water dump nozzle orifice: 0.055 in.

2.7.4.8 ECS Power Consumption Data.

The following list contains the latest available data on electrical power consumed by components of the ECS. The wattage figures are for the earth orbit phase only, and apply to operations during the normal mode (pressurized cabin).

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Subsystem and Component	Control	No. of Units	Watts per Unit		Total Watts	
			AC	DC	AC	DC
OXYGEN SUPPLY						
O <sub>2</sub> flow transducer	ECS-TRANSDUCER- PRESS GROUPS-2 cb (2)	1		2.4		2.4
O <sub>2</sub> press transducer	ECS-TRANSDUCER- PRESS GROUPS-2 cb (2)	1		0.8		0.8
PRESSURE SUIT CIRCUIT						
Suit compressor	SUIT COMPRESSORS sw	2	85.0		†85.0 170.0	
ΔP sensor	ECS-TRANSDUCER- PRESS GROUPS-1 cb (2)	1		1.28		1.28
CO <sub>2</sub> sensor	ECS-TRANSDUCER- PRESS GROUPS-2 cb (2)	1		1.0		1.0
Diverter valve control unit	SUIT EVAP sw	1	2.5		2.5	
Diverter control valve	SUIT EVAP sw	1	*7.2		*7.2	
Steam press control unit	SUIT EVAP sw	1	2.5		2.5	
Steam press cont valve	SUIT EVAP sw	1	*7.2		*7.2	
Steam duct abs press sensor	SUIT EVAP sw	1		1.28		1.28
Wetness control unit	SUIT EVAP sw	1	5.0		5.0	
Water inflow control valve	SUIT EVAP sw	1		*3.0		*3.0
Wetness sensor	SUIT EVAP sw	1		0.2		0.2
Water-gly temp sensor	SUIT EVAP sw	1		0.001		0.001
Evap outlet air temp sensor	SUIT EVAP sw	1		0.001		0.001

\*Intermittent operating components

†Only one component operates at a time

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Subsystem and Component	Control	No. of Units	Watts per Unit		Total Watts	
			AC	DC	AC	DC
Suit press transducer	ECS-TRANSDUCER- PRESS GROUPS-1 cb (2)	1		0.8		0.8
Suit temp sensor	ECS-TRANSDUCER- TEMP GROUP cb (2)	1	0.04		0.04	
CABIN PRESSURE & TEMP CONTROL						
Cabin air fan	CABIN AIR FAN-1&2 sw (2)	2	19.0		38.0	
Cabin temp control unit	CABIN TEMP-AUTO/ MAN sw	1	2.5		2.5	
Cabin temp cont valve	CABIN TEMP-AUTO/ MAN sw	1	*7.2		*7.2	
Cabin temp sensor	ECS-TRANSDUCER- TEMP GROUP cb (2)	1		0.001		0.001
Cabin temp anticipator	ECS-TRANSDUCER- TEMP GROUP cb (2)	1		0.001		0.001
Cabin press transducer	ECS-TRANSDUCER- PRESS GROUPS-2 cb (2)	1		0.8		0.8
WATER-GLYCOL COOLANT						
Water-glycol pump	ECS GLYCOL sw	2	36.0		†36.0	
Pump outlet press transducer	ECS-TRANSDUCER- PRESS GROUPS-1 cb (2)	1		0.8		0.8
Water-gly accum qty sensor	ECS-TRANSDUCER- PRESS GROUPS-1 cb (2)	1		0.8		0.8

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\*Intermittent operating components

†Only one component operates at a time

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Subsystem and Component	Control	No. of Units	Watts per Unit		Total Watts	
			AC	DC	AC	DC
Water-gly temp control unit	GLYCOL EVAP-TEMP IN sw	1	2.5		2.5	
Water-gly temp control valve	GLYCOL EVAP-TEMP IN sw	1	*7.2		*7.2	
Water-gly temp sensor	GLYCOL EVAP-TEMP IN sw; GLY EVAP-STEAM PRESS-AUTO/MAN sw; GLYCOL EVAP-H <sub>2</sub> O FLOW sw	5		0.001		0.005
Steam press control unit	GLY EVAP-STEAM PRESS-AUTO/MAN sw	1	2.5		2.5	
Steam press cont valve	GLY EVAP-STEAM PRESS-INCR/DECR sw	1	*7.2		*7.2	
Steam duct press switch	ECS-TRANSDUCER-PRESS GROUPS-1 cb (2)	1	TBD	TBD	TBD	TBD
Water control unit	GLYCOL EVAP-H <sub>2</sub> O FLOW sw	1	5.0		5.0	
Water control valve	GLYCOL EVAP-H <sub>2</sub> O FLOW sw	1		*3.0		*3.0
Wick temp sensor	GLYCOL EVAP-H <sub>2</sub> O FLOW sw	1		0.28		0.28
Rad outlet temp sensor	ECS-TRANSDUCER-TEMP GROUP cb (2)	1	0.04		0.04	
Rad isolation valve	ECS RADIATOR sw (4)	4	*14.4		*57.6	

\*Intermittent operating components

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Subsystem and Component	Control	No. of Units	Watts per Unit		Total Watts	
			AC	DC	AC	DC
WATER SUPPLY						
Pot water qty transducer	ECS-TRANSDUCER-WASTE & POT H <sub>2</sub> O-MN A&B cb (2)	1		1.28		1.28
Waste water qty transducer	ECS-TRANSDUCER-WASTE & POT H <sub>2</sub> O MN A&B cb (2)	1		1.28		1.28
Food prep water supply unit	POT H <sub>2</sub> O HEATER sw	1		*45.0		*45.0
H <sub>2</sub> O accum control unit	H <sub>2</sub> O ACCUM-AUTO/MAN sw	1		3.0		3.0
H <sub>2</sub> O accum valve	H <sub>2</sub> O ACCUM-ON/OFF sw	2		*3.0		*3.0
H <sub>2</sub> O accum fail sensor	ECS-H <sub>2</sub> O ACCUM-MN A&B cb (2)	1		1.5		1.5
S/M water tank shut-off valve	WASTE H <sub>2</sub> O TK REFILL sw	2		*160.0		*160.0
MISCELLANEOUS						
WMS blower	WASTE MANAGEMENT SELECTOR valve	1	*20.0			*20.0
Urine/water dump nozzle heater	ECS-STEAM DUCT HTR-MN A&B cb (2)	1		5.7		5.7
Steam duct heater	ECS-STEAM DUCT HTR-MN A&B cb (2)	2		3.0		6.0
Temp xducer pwr supply	ECS-TRANSDUCER-TEMP GROUP cb (2)	1		10.5		10.5

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\*Intermittent operating components

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Subsystem and Component	Control	No. of Units	Watts per Unit		Total Watts	
			AC	DC	AC	DC
Temp sensor amplifier	ECS-TRANSDUCER- TEMP GROUP cb (2)	5	0.04		0.2	
Steam duct temp sensor signal conditioner	ECS-TRANSDUCER- TEMP GROUP cb (2)	1		1.5		1.5
Gas chromatograph	GAS ANAL—AC 1 cb	1	9		9	

\*Intermittent operating components

2.7.5 OPERATIONAL LIMITATIONS AND RESTRICTIONS

2.7.5.1 ECS Caution Placards.

Caution notes bordered by yellow and black stripes appear adjacent to the postlanding vent valves in the forward tunnel area. The notes read, "POST LANDING VENT VALVE—PULL PIN BEFORE OPERATING VENT FAN." If the pins were not in place during flight, inadvertent opening of the cabin vent valves would immediately dump all cabin pressure, with possible catastrophic results.

A placard on each CO<sub>2</sub>-odor absorber canister cover cautions the crewman to "PUSH BUTTON BEFORE OPENING," and includes an arrow to indicate direction button should be pushed. This instruction must be followed any time a canister cover is to be opened. By pressing the push-button, the differential pressure is equalized and the cover may then be removed.

The caution note on LHEB-314 pertains to filling the PLSS oxygen tanks and, therefore, is not applicable to earth orbital (Block 1) missions. It reads, "CAUTION 900 PSI CLOSE VALVE BEFORE REMOVING CAP."

2.7.5.2 ECS Caution Notes.

Design restrictions require that certain procedures be followed when positioning the inlet and outlet selector valves of the tank pressure regulator and relief valve assembly. If the inlet selector valve is placed to position 1 (or 2), the outlet selector valve must also be placed to position 1 (or 2) or to NORMAL position. This prevents shutting off the supply of oxygen for pressurizing the potable and waste water tanks and the water-glycol reservoir. Conversely, if the outlet selector valve is placed to position 1 (or 2), the inlet selector valve must be placed to position 1 (or 2) or to NORMAL position.

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2.7.5.3 ECS General Data.

Several ECS controls are inaccessible during the mission. Those affected are located behind the two removable Y-axis attenuator panels in the LHEB. They include all controls mounted on LHEB-311, the suit circuit return air manual valve, and the diverter valve handle for the CO<sub>2</sub>-odor absorber canisters. The attenuator panels are in place during the entire mission, but are removed to gain access to these ECS controls, and then immediately reinstalled. They provide an adequate bearing surface for the Y-axis attenuator shock strut pad for the landing impact.

The circuit breaker for the postlanding ventilation system is not engaged until after landing impact. This precaution, in conjunction with the lockpins previously inserted in the postlanding vent valves, assures that the cabin pressure will not be inadvertently dumped during flight.

High-oxygen flow during cabin repressurization, or when filling an empty (150 psia min) surge tank, may cause water-glycol freezing. This will occur when there is less than full flow through the warm water-glycol line upon which the flow restrictors are wound. Full coolant flow at this location, therefore, may be assured in the following manner. Between 15 and 30 minutes prior to anticipated high oxygen flow, set the GLYCOL EVAP-TEMP IN switch (MDC-13) to MAN, and override the GLYCOL EVAP TEMP IN valve (LHEB-311) to the full cool position.

Radiator heat rejection (as freezing) is a function of radiator inlet temperature and radiator orientation. Thus, if the radiator inlet temperature decreases to 75°F, the S/C must be placed in a 2 to 5 RPH (0.2 to 0.5 degree per second) roll rate. During this time radiator inlet temperature must not decrease below 70°F, or the individual radiator outlet temperature below 30°F.

ECS

2.7.5.4 Cabin Depressurization Rates.

The time required for the C/M cabin to become depressurized is contingent upon how pressure is released. If the cabin is intentionally dumped, the time it takes to reach zero pressure will be as shown in figure 2.7-11, sheet 1 of 2. However, if the pressure is lost as the result of meteoroid punctures, the time will vary according to the size and number of holes. Figure 2.7-11, sheet 2 of 2, only reflects flow rate data for meteoroid holes that do not exceed a total equivalent area of 0.5 in. in diameter. The same chart also applies to the flow rate of one cabin pressure relief valve that has failed open while in the NORMAL position.

2.7.5.5 Cabin Repressurization Rates.

The C/M cabin may be repressurized by using either of two flow rates. To return the cabin pressure to normal in the shortest possible time, the conditions as set forth in figure 2.7-12, sheet 1 of 2, must be complied with. The flow rate, however, is dependent upon a full supply of oxygen in the

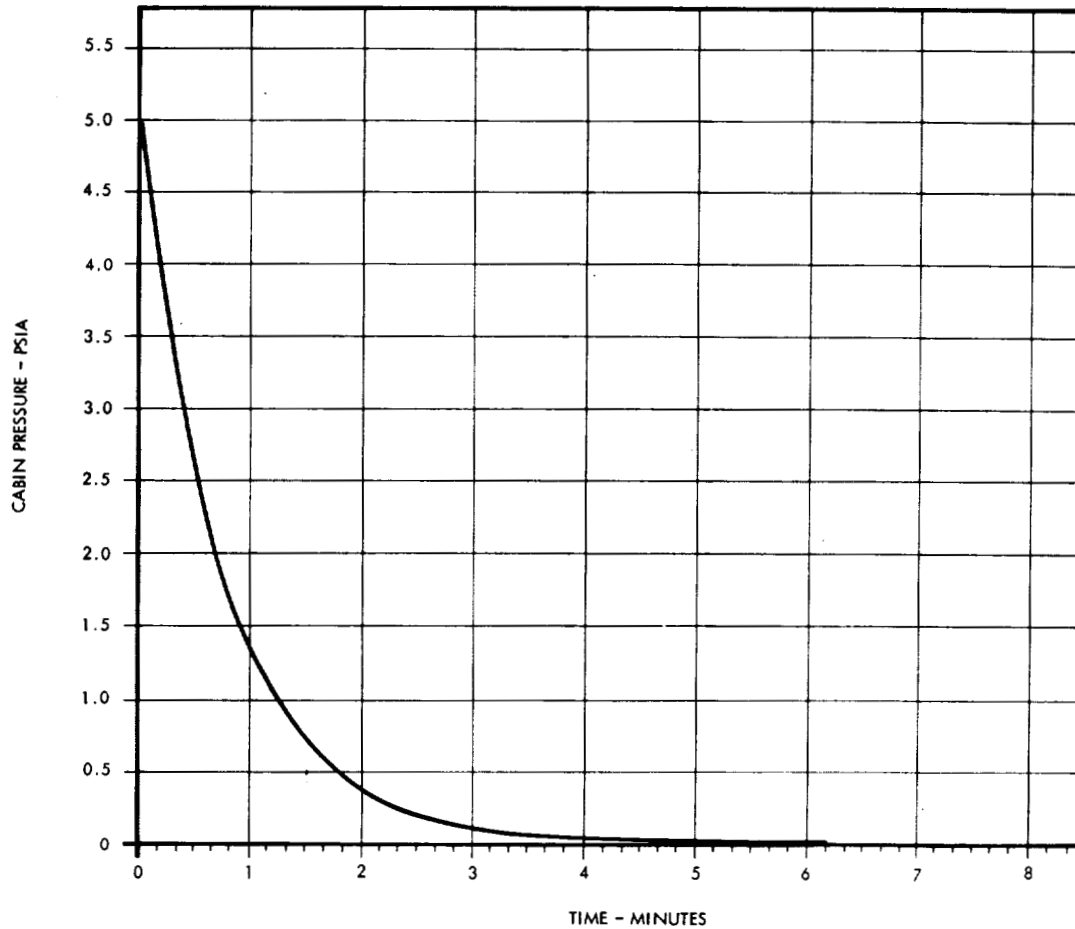
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ENVIRONMENTAL CONTROL SYSTEM

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CABIN DEPRESSURIZATION - 5 TO 0 PSIA  
INTENTIONAL DUMP TIME - 6 MIN, 11 SEC



- CONDITIONS: 1. EMERGENCY CABIN PRESSURE selector valve set to OFF.  
2. CABIN REPRESS manual valve set to close.  
3. CABIN PRESSURE RELIEF valve set to DUMP.  
4. Normal cabin pressure regulators automatically close at 3.5 psia.

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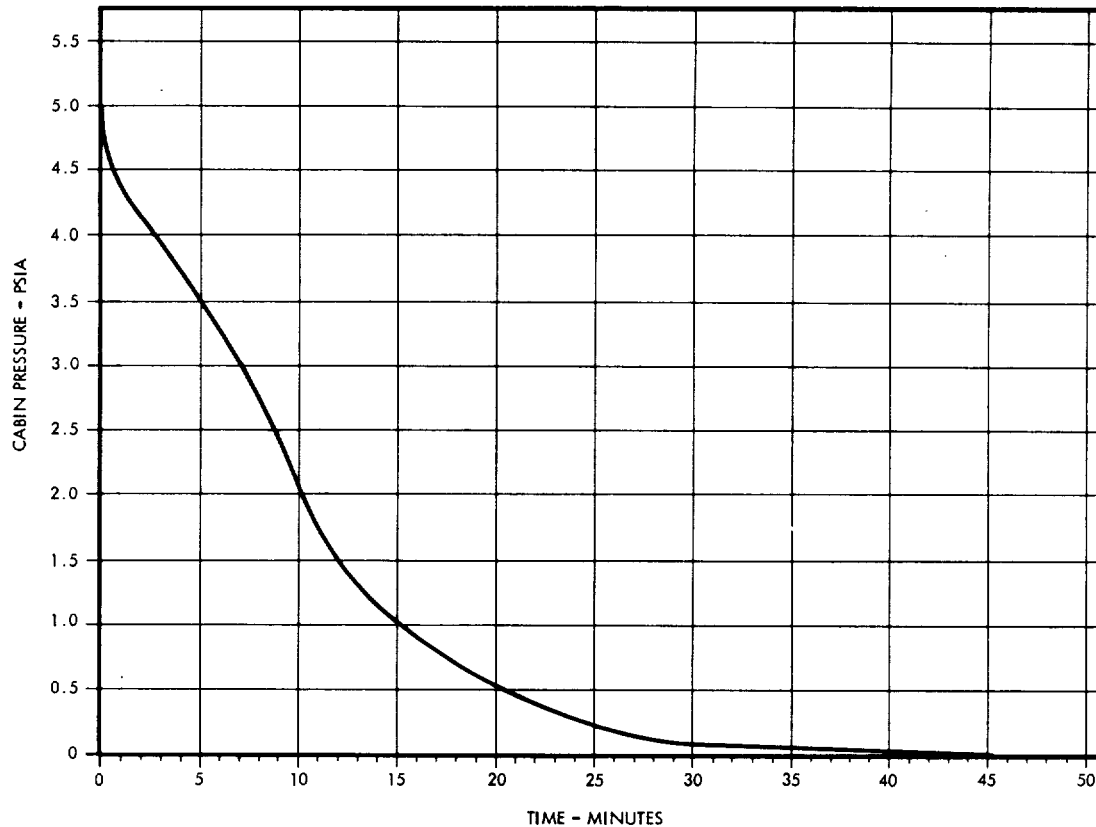
Figure 2.7-11. Cabin Depressurization Rates (Sheet 1 of 2)

ENVIRONMENTAL CONTROL SYSTEM

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CABIN DEPRESSURIZATION - 5 TO 0 PSIA  
UNINTENTIONAL DUMP TIME - 45 MIN, 40 SEC\*



ECS

- CONDITIONS: 1. EMERGENCY CABIN PRESSURE selector valve set to NORMAL.  
2. CABIN REPRESS manual valve set to close  
3. CABIN PRESSURE RELIEF valves set to NORMAL.  
4. Normal cabin pressure regulators automatically closed at 3.5 psia.  
5. EMERGENCY CABIN PRESSURE selector valve set to OFF position when pressure reaches 3.5 psia (5 minutes).

\*Depressurization is through a 0.5-inch-diameter (or equivalent) meteoroid puncture, or the maximum flow through one CABIN PRESSURE RELIEF valve that fails open while in the NORMAL position.

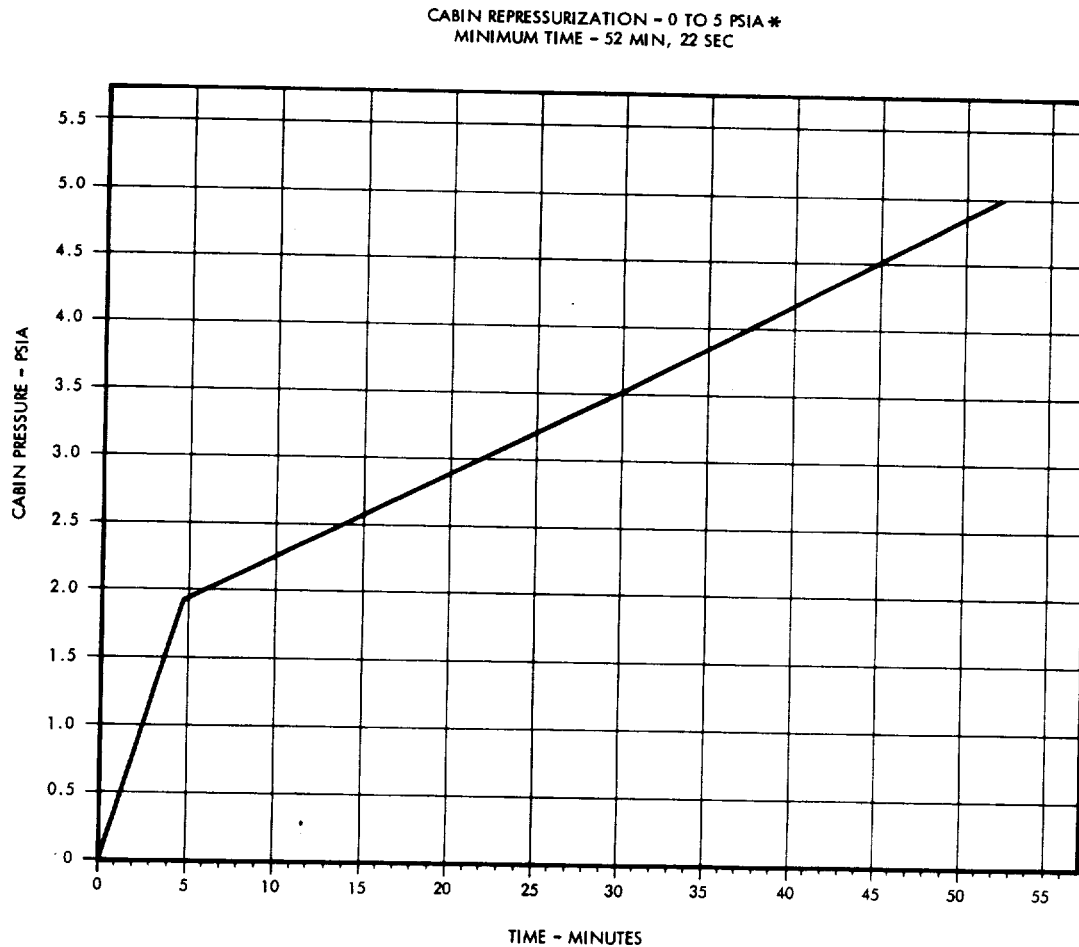
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Figure 2.7-11. Cabin Depressurization Rates (Sheet 2 of 2)

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- CONDITIONS: 1. EMERGENCY CABIN PRESSURE selector valve set to NORMAL.
2. CABIN REPRESS manual valve set to OPEN.
3. When surge tank pressure indicator decreases to 150 psia, EMERGENCY CABIN PRESSURE selector valve set to OFF; surge tank minimum pressure (150 psia) maintained by regulating CABIN REPRESS manual valve until valve is full open and surge tank pressure starts to increase.
4. Normal cabin pressure regulators automatically open at 3.5 psia.
5. When surge tank pressure again decreases to 150 psia, CABIN REPRESS manual valve regulated to maintain this minimum surge tank pressure.
6. When cabin pressure indicator reaches 5.0 psia, normal cabin pressure regulators automatically close and CABIN REPRESS manual valve set to close.

\* Requires 9.1lb oxygen at 70°F cabin temperature

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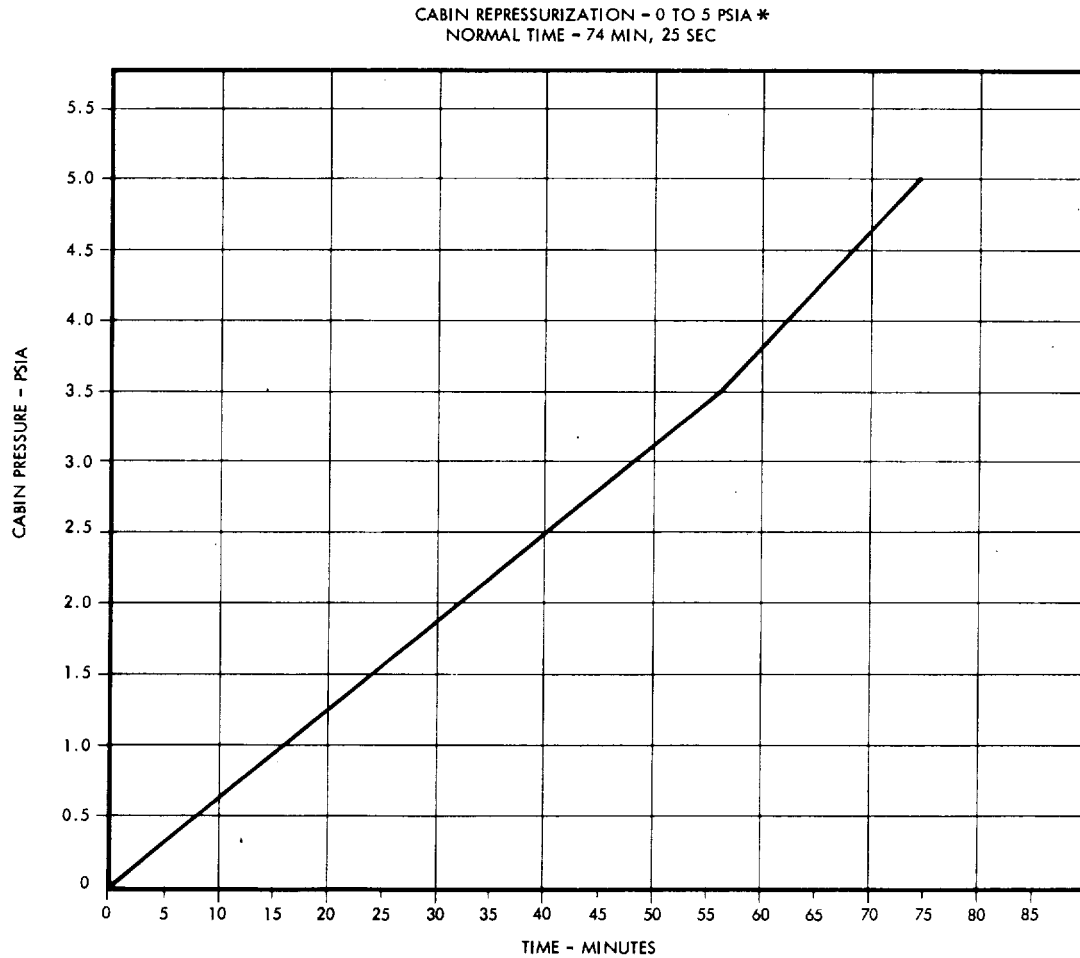
Figure 2.7-12. Cabin Repressurization Rates (Sheet 1 of 2)

ENVIRONMENTAL CONTROL SYSTEM



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- CONDITIONS: 1. EMERGENCY CABIN PRESSURE selector valve set to OFF.
2. CABIN REPRESS manual valve set to OPEN.
3. Normal cabin pressure regulators automatically open at 3.5 psia.
4. When cabin pressure indicator reaches 5.0 psia, normal cabin pressure regulators automatically close and CABIN REPRESS manual valve set to close.

\* Requires 9.1lb oxygen at 70°F cabin temperature

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Figure 2.7-12. Cabin Repressurization Rates (Sheet 2 of 2)

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surge tank. When the surge tank is not full, or the repressurization time is not critical, the conditions for the flow rate as shown in figure 2.7-12, sheet 2 of 2, are used.

2.7.6 TELEMETRY MEASUREMENTS.

The following is a complete list of all ECS telemetry data that is monitored by flight controllers and ground support personnel. The last column contains the name and type of S/C crew display. The display utilizes the same pickoff or signal source as telemetry, unless a separate measurement number is included in the display column.

An asterisk (\*) by the measurement number denotes information which is not available for recording or telemetry transmission during PCM low-bit rate operation.

Measurement Number	Description	Sensor Range	Normal Operating Range	Crew Display
CF 0001 P	Pressure cabin	0/17 psia	5.0±0.2 psia	PRESS - CABIN indicator
CF 0002 T	Temp cabin	40/125°F	70° to 80°F	TEMP - CABIN indicator
CF 0005 P	Press CO <sub>2</sub> partial	0/30 mm Hg	<7.6 mm Hg	PART PRESS CO <sub>2</sub> indicator and CO <sub>2</sub> PP HI C&W light
*CF 0006 P	Press surge tank	50/1050 psia	900±35 psia	TANK PRESS - 1 - O <sub>2</sub> indicator
*CF 0008 T	Temp suit supply manifold	20/95°F	55°F	TEMP - SUIT indicator
CF 0009 Q	Quantity waste water tank	0/100%	Variable	WATER - QUANTITY indicator
CF 0010 Q	Quantity potable H <sub>2</sub> O tank	0/100%	Variable	WATER - QUANTITY indicator
CF 0012 P	Press suit demand reg sense	0/17 psia	3.75±0.25 psia	PRESS - SUIT indicator
CF 0015 P	Press suit compressor diff	0/1 psid	Min 0.3 to 0.4 psid	ΔP SUIT COMPR indicator
CF 0016 P	Press glycol pump outlet	0/60 psia	37 to 45 psia	PRESS GLY DISCH indicator

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Measurement Number	Description	Sensor Range	Normal Operating Range	Crew Display
*CF 0017 T	Temp glycol evap outlet steam	20/95°F	>45°F	None
CF 0018 T	Temp glycol evap outlet liquid	25/75°F	40° to 50.5°F	GLY EVAP - OUTLET TEMP indicator
CF 0019 Q	Quantity glycol accum	0/100%	40 to 60%	GLY ACCUM - QUANTITY indicator
CF 0020 T	Temp space radiator outlet	-50/+100°F	Variable	ECS RAD - OUTLET TEMP indicator and GLYCOL TEMP LOW C&W light
*CF 0025 P	Press pump package inlet	0/60 psia	7 psi min	None
CF 0034 P	Back press glycol evaporator	0.05/0.25 psia	0.098 to 0.154 psia	GLY EVAP STEAM PRESS indicator
CF 0035 R	Flow rate ECS O <sub>2</sub>	0.2/1.0 lb/hr	0.425 lb/hr	FLOW O <sub>2</sub> indicator
*CF 0036 P	Press outlet O <sub>2</sub> reg supply	0/150 psia	100±10 psia	None
*CF 0120 P	Press H <sub>2</sub> O and glycol tanks	0/50 psia	18 to 35 psid	None
*CF 0135 R	Flow rate manifold inlet to suit 1	0/0.2 lb/hr	TBD	None
*CF 0136 R	Flow rate manifold inlet to suit 2	0/0.2 lb/hr	TBD	None
*CF 0137 R	Flow rate manifold inlet to suit 3	0/0.2 lb/hr	TBD	None
*CF 0148 P	DP supply and return manifold	0/0.8 psid	0.25 to 0.5 psid	None
*CF 0153 T	Temp compressor inlet	50/125°F	TBD	None
*CF 0184 T	Temp CO <sub>2</sub> absorber outlet	90/200°F	TBD	None

ECS

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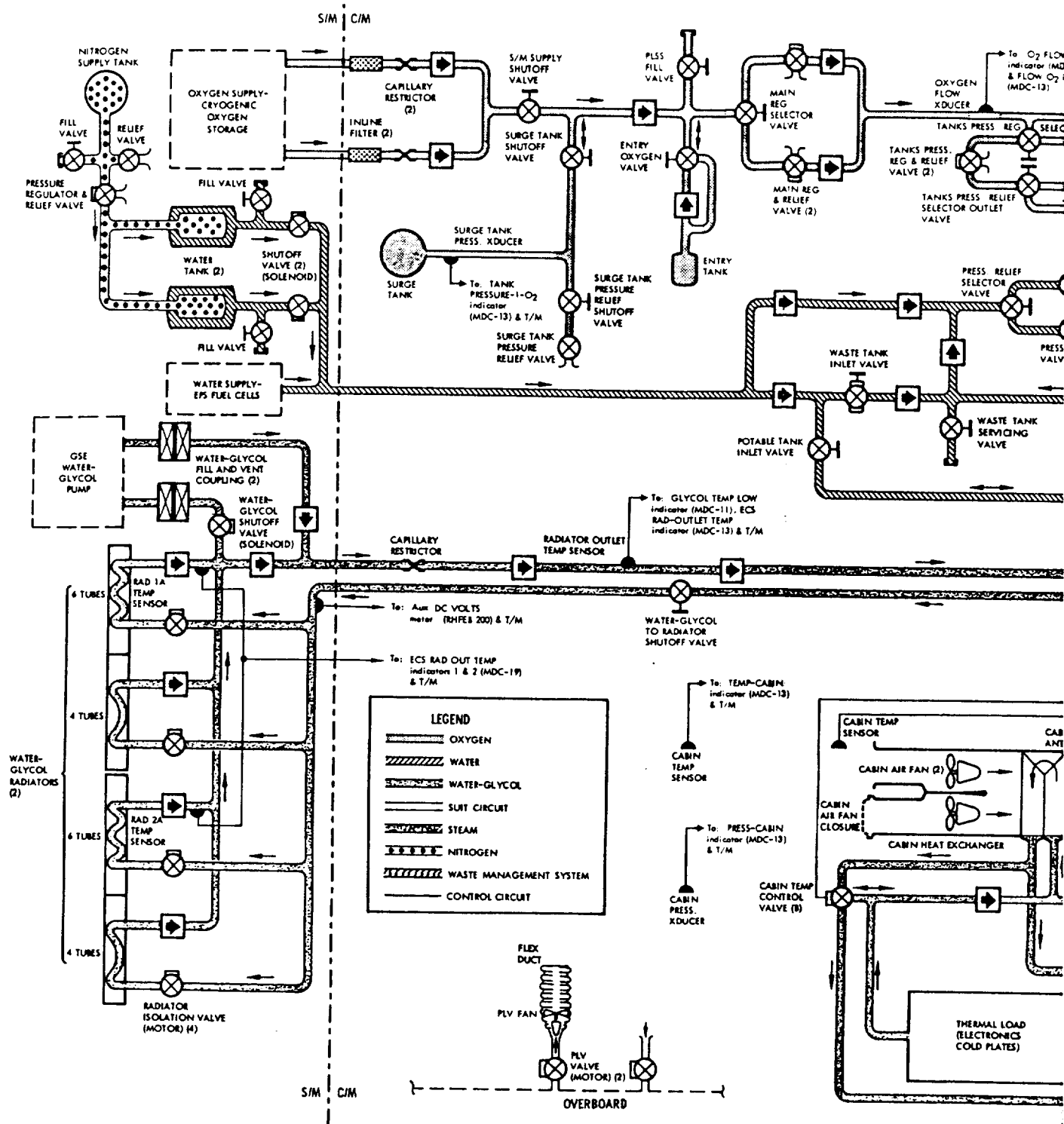
Mission \_\_\_\_\_ Basic Date 12 Nov 1966 Change Date \_\_\_\_\_ Page 2.7-45

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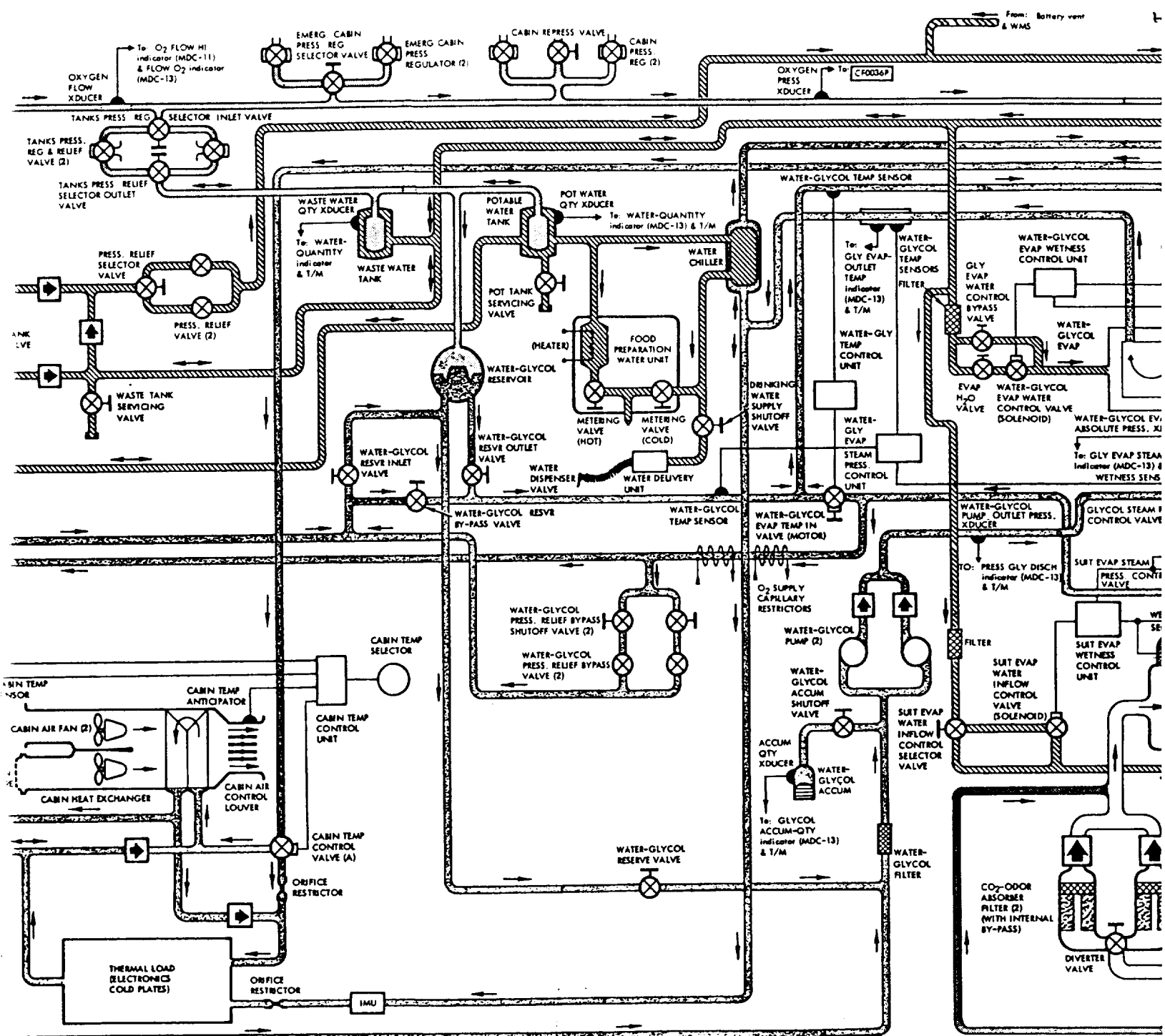
Measurement Number	Description	Sensor Range	Normal Operating Range	Crew Display
*CF 0245 T	Temp O <sub>2</sub> reg inlet	-50/+150°F	TBD	None
*CF 0326 P	Press potable H <sub>2</sub> O tank drain	0/50 psia	18 to 35 psid	None
*CF 0327 P	Press waste H <sub>2</sub> O tank drain	0/50 psia	18 to 35 psid	None
*CF 0481 T	Temp CP branch 1 inlet	40/150°F	TBD	None
*CF 0482 T	Temp CP branch 1 outlet	40/150°F	TBD	None
*CF 0483 T	Temp CP branch 2 inlet	40/150°F	TBD	None
*CF 0484 T	Temp CP branch 2 outlet	40/150°F	TBD	None
*CF 0549 P	Diff press coldplate branch 1	0/2.0 psid	TBD	None
*CF 0550 P	Diff press coldplate branch 2	0/10 psid	TBD	None
CT 0108 K	Gas analysis - suit and cabin	N/A	N/A	None
SF 0665 T	Temp space radiator inlet	60/150°F	Variable	None
SF 0671 T	Temp ECS radiator outlet 1	0/50°F	Variable	ECS RAD OUT TEMP-1 indicator
SF 0672 T	Temp ECS radiator outlet 2	0/50°F	Variable	ECS RAD OUT TEMP-2 indicator

ENVIRONMENTAL CONTROL SYSTEM



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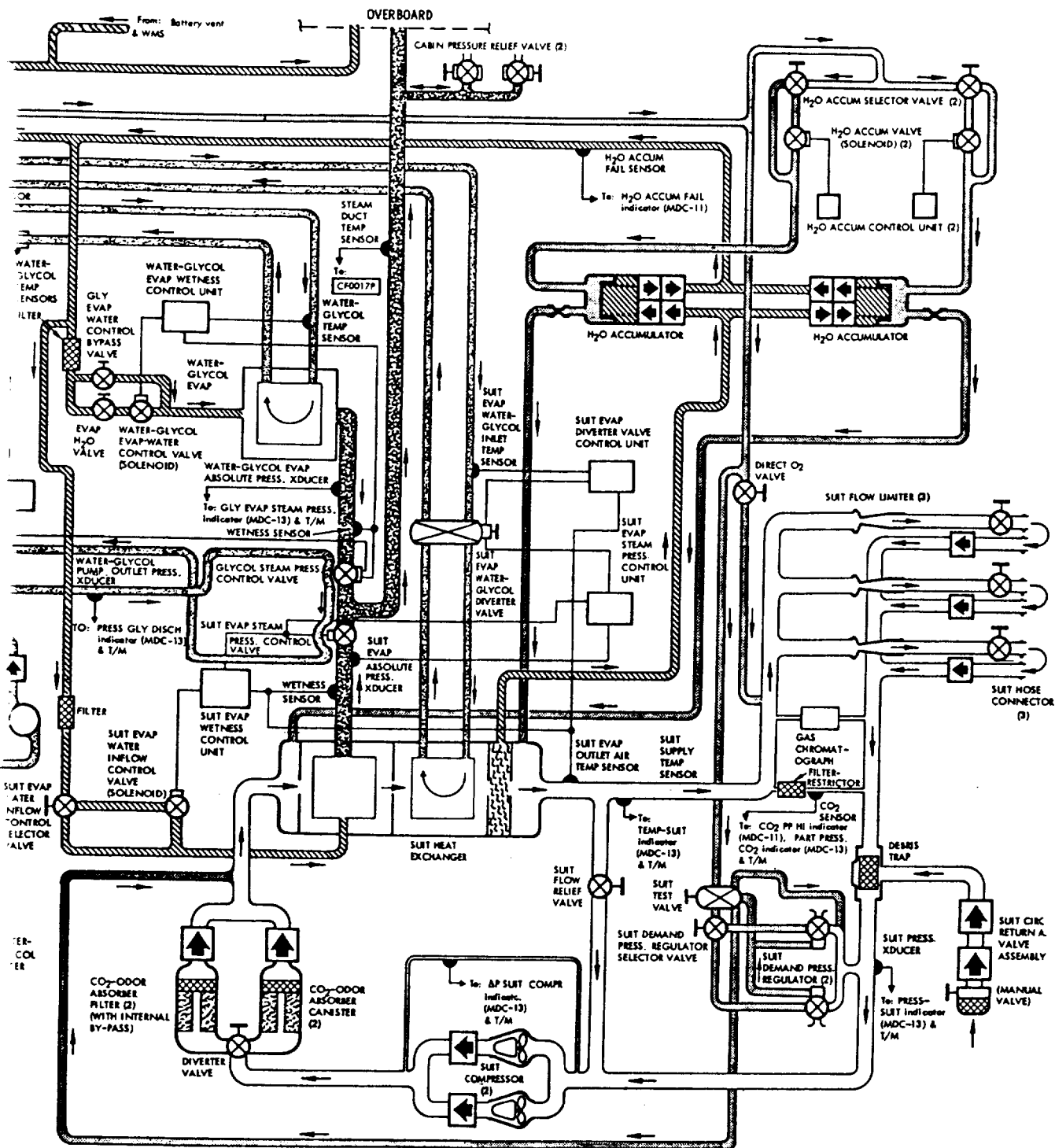
**BOEING FRAME**

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Figure 2.7-13. ECS Schematic Diagram

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RODOUT EXAM

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SECTION 2

SUBSECTION 2.8

TELECOMMUNICATION SYSTEM

2.8.1 INTRODUCTION.

The telecommunication (T/C) system includes the spacecraft (S/C) communications and data equipment required for voice communications; acquisition, processing, storage and transmission of operational and flight qualification telemetry (TLM), television (TV), and biomedical data; reception of up-data; and transmission of appropriate tracking and ranging signals. At least part of the T/C system will be in operation during all phases of the mission—from prelaunch through recovery. The following list summarizes T/C capabilities as utilized on SC-012.

- S/C intercommunications between crewman
- Hardline voice communications and transmission of TV and TLM data to the Launch Control Center (LCC) via the service module umbilical (USM) during prelaunch
- In-flight voice communications with the manned spaceflight network (MSFN)
- Voice tape recording of comments, observations, opinions, etc., with time correlation
- Acquisition and processing of TLM, TV, and operational biomedical data from the S/C structure and systems, TV camera, and crewman biomedical sensors, respectively
- TLM data storage
- Transmission of real-time or stored TLM data
- Reception of up-data (guidance and navigation, and timing data and real-time commands) from the MSFN
- Transmission of C-band tracking pulses in response to received radar signals
- Limited capabilities for S-band operation, including transmission of voice and TLM data plus TV, stored analog, or pseudo-random noise (PRN), ranging codes, and reception of voice and up-data
- Postlanding recovery aids including voice communications and recovery beacon transmission

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- Generation of timing signals for synchronization of the T/C and other S/C systems.

2.8.2 FUNCTIONAL DESCRIPTION.

The functional description of the T/C system is divided into four parts: voice communications, data operations, tracking and ranging, and S-band operations. The unified S-band subsystem (USBS), used for all S-band operations, provides back-up voice, data, tracking and ranging capabilities, and the sole means for transmission of TV or analog data.

2.8.2.1 Voice Communications.

2.8.2.1.1 General.

All S/C voice communications (figure 2.8-1) originate and terminate in the crewmen's personal communication assemblies (headsets). Each crewman has two headsets; one is located in the "bump-hat" for use while wearing the constant-wear garment; the other is located in the spacesuit helmet. Each headset is comprised of two independently operating ear-phones and two microphones with self-contained preamplifiers. The headsets are used for all voice transmission and reception.

Each crewman's headset is connected to the audio center (A/C) equipment by a separate electrical umbilical assembly, commonly referred to as a "cobra cable." In addition to the audio circuits, each of the three cobra cables contains wiring for the operational biomedical sensors in the constant wear garments and the push-to-talk (PTT) control circuitry. The PTT control circuitry consists of a pushbutton-type PTT key and a PTT/CW selector switch. With the PTT/CW selector switch in the PTT position, the PTT key permits manual control of voice transmission by the appropriate transmitter and mike amplifier circuit in the audio center module.

The PTT mode was designed to be used during the launch phase of the mission when high noise levels would preclude usage of the VOX circuitry. In this mode, the PTT key will enable the microphone amplifier, voice recorder, VHF-AM and S-Band transmitters if the latter three have their attendant control switches configured properly. The audio center power switch and the cobra cable mode switch would be in PTT position during this mode.

The CW mode was also designed to be used during the high-noise levels of the launch phase. In this mode, however, the VHF and S-band downvoice communications links are not enabled. This gives us a PTT controlled intercommunications. The voice recorder could also be enabled in this mode if needed. The audio center power switch would also be in the PTT position, but the mode switch on the cobra cable must be in the CW position. It should be noted that on older cobra cables, the CW position was used only for emergency key. Now, this position will be used for both

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emergency key and the PTT intercommunications functions. PTT keys are also located on the translation controls. Their function duplicates that of the PTT key with the PTT/CW selector in the PTT position on the cobra cable.

The head of each cobra cable has two electrical connectors, marked NORM and EMER. Normally, the connector marked NORM will be used; however, in the event of failure in one of the A/C modules, the affected crewman may connect the cable from his spacesuit to the connector marked EMER. This will connect his audio circuits to another A/C module and allow the same module to be shared by two crewmen.

A strap has been added to the cobra cable so the PTT button can be held in the ON position if desired. This would allow a continuous intercom if the Audio center POWER switch, (MDC 13, 23, 26) is in the PTT position.

The A/C equipment contains three separate but identical modules, one for each crewman, and a commonly connected intercom bus. This equipment serves as a control and distribution center for all S/C audio signals. Each of the three modules has a separate but identical set of controls located on MDC-26, -13, and -23 for the command pilot, senior pilot, and pilot, respectively. Thus each crewman is provided with independent control of all audio inputs and outputs to and from his own headset. A POWER switch on each panel controls application of power to its respective A/C module and selects the PTT or voice-operated relay (VOX mode) of operation. The PTT mode permits monitoring of incoming audio signals plus PTT activation of the microphone amplifier, voice recorder, and the enabling of any communications transmitters if their attendant control switches are properly configured.

The VOX mode permits the microphone amplifier to be activated by the voice-operated switching circuitry within the audio center. The audio output of the amplifier is then applied to isolation and switching diodes controlled in part by the audio center controls located on panels MDC-26, -13, and -23.

Voice transmission over, the activated unified S-band equipment is allowed by placing the S-BAND switch to REC (MDC-26, -13, -23), setting the cobra cable PTT/CW switch at PTT and closing the PTT pushbutton on either the cobra cable or the translation controls.

Voice transmission over, the HF transceiver is limited to the post-landing phase of the mission; however, the RCDR/HF switch (MDC-26, -13, -23) in the T/R position provides a ground for the power control relay in the voice recorder. The intercom switch (MDC-26, -13, -23) would also have to be in the T/R position so the audio signal would be available for recording.

Voice transmission over, the activated VHF-AM transmitter is allowed by placing the VHF-AM switch to T/R (MDC-26, -13, -23), setting the cobra cable PTT/CW switch to PTT, and closing the PTT pushbutton on either the cobra cable or the translation controls. Monitoring the VHF-AM is provided by placing the VHF-AM T/R/OFF/REC switch to REC.

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Each audio control panel has three thumbwheel-type potentiometer controls: a VOX SENS control for adjusting the sensitivity of the VOX circuit, an INTERCOM BALANCE control for decreasing the level of the audio signals received from the RF equipment relative to that received from the intercom bus, and a VOLUME control for changing the overall level of all audio signals to the earphones. Each channel, in the A/C modules, also contains sidetone circuitry which enables a crewman to monitor his own transmission.

2.8.2.1.2 S/C Intercommunications.

S/C intercommunications and hardline voice communications are conducted via the intercom bus, which is commonly connected to each of the three A/C modules, to the LCC during prelaunch via the USM, and to recovery forces via the swimmer electrical connector during recovery operations. To communicate, a crewman must activate his A/C module by placing the POWER switch to VOX or PTT and setting the INTERCOM switch to T/R.

An A/C intercom transmission can only be initiated with the PTT key, if the PTT position of the power switch is selected. In the VOX position, either the VOX circuit or the PTT key will indicate an intercom transmission. If only an intercom transmission is desired, the PTT/CW switch on the cobra cable should be in the CW position. Normally, the A/C modules will remain activated throughout the entire mission.

2.8.2.1.3 In-Flight Voice Communications.

In-flight voice communications with the MSFN will be conducted over the USBS and the VHF-AM transmitter-receiver equipment. Controls for the S-band and the VHF-AM groups are located on MDC-20, and MDC-26, -13, and -23. The VHF-AM controls on MDC-20 consist of a T/R/OFF/REC switch that controls application of power, a RCVR switch to control which of two receiver modes 1 simplex, 2 duplex, are operational, a SQUELCH control to establish the level of RF signal required to pass audio signals to the audio center, and a VHF ANTENNA switch to manually select the upper (+Z), or lower (-Z), antenna. Voice transmission via VHF-AM is controlled by the placement of the VHF-AM switch (MDC-26, -13, or -23) to T/R, the cobra cable MODE switch to PTT, and depressing the PTT pushbutton on the cobra cable. Either T/R or REC permits voice reception from the MSFN.

T/C

Voice communication is possible in all operational modes of the USBS, with the exception of the emergency key mode, providing the S-BAND switch (MDC-26, -13, or -23) is placed at REC. Transmission is controlled by the PTT pushbutton on the cobra cable, providing the cobra cable MODE switch is in the PTT position. (Refer to paragraph 2.8.3.3.4 for additional information on the unified S-band operations.)

2.8.2.1.4 Recovery Voice Communications.

After touchdown, the HF transceiver equipment will be utilized for voice communications. It is controlled by the RECOVERY-HF switches on

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MDC-20 which include an ON-OFF switch and a SSB/BCN/AM switch for selecting mode. Either the single sideband (SSB) or amplitude modulation (AM) modes may be used for voice communications. The beacon (BCN) mode is used to transmit a continuous wave beacon for tracking purposes.

Voice transmission in either the SSB or AM mode can be VOX- or PTT-controlled when the RCDR/HF switch (MDC-26, -13, -23) is placed to T/R.

The HF transceiver utilizes the HF recovery antenna. This antenna must be deployed after touchdown by setting the POSTLANDING—ANTENNA DEPLOY switches on MDC-25 to their upper positions, A and B, while the MASTER EVENT SEQ CONT switches 1 and 2 (MDC-24) are at arm and MASTER EVENT SEQ CONT ARM A and B circuit breakers (MDC-22) are closed.

The VHF/AM transmitter-receiver equipment can be used as backup by utilizing VHF recovery antenna No. 2 which can be selected by setting the VHF ANTENNA switch (MDC-20) to RECOVERY. Also, the GFAE survival transceiver can be used inside the S/C by connecting its coaxial cable to VHF recovery antenna No. 1 or No. 2 at the coaxial bracket, MDC-9. These coaxial connectors may be utilized, during the interval preceding the arrival of the recovery forces, in the most advantageous manner. Any combination of VHF recovery beacon, GFAE survival transceiver, and VHF-AM transmitter-receiver may be employed as warranted by the serviceability of the communications equipment.

2.8.2.2 Data Operations.

2.8.2.2.1 General.

T/C system data capabilities include the processing, storage, and transmission of TLM data to the MSFN; the reception and processing of up-telemetry data (up-data) received from the MSFN; and during USBE testing, the transmission of TV from the TV camera. In addition to transmitted data, verbal comments may be recorded on the voice recorder. (See figure 2.8-2.)

2.8.2.2.2 TLM Transmission and Storage.

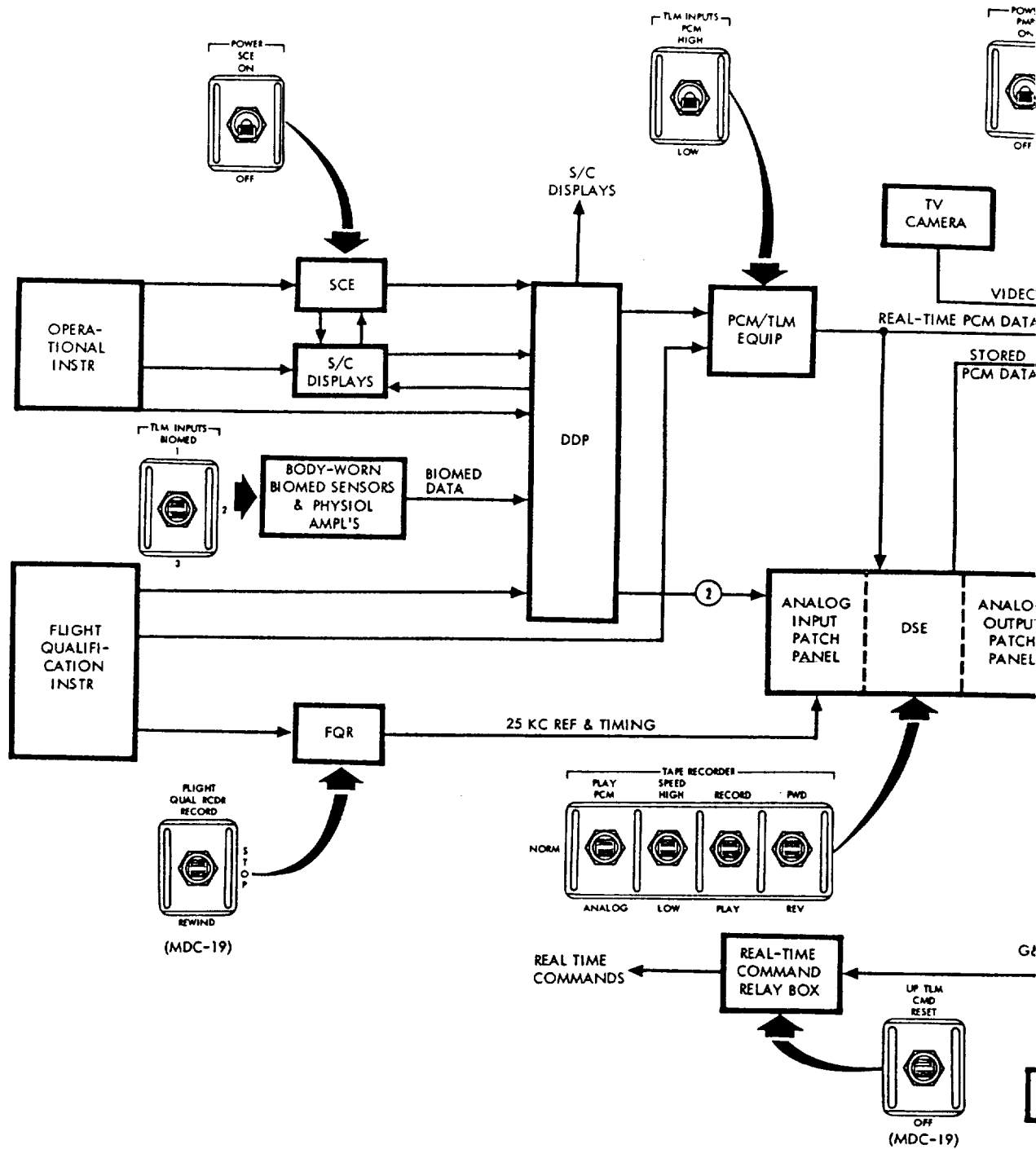
TLM data may simultaneously be transmitted via VHF-FM and/or S-band and recorded in the DSE for delayed time transmission when requested by MSFN. The system configuration prohibits transmission or recording of real time data while transmitting stored data.

TLM data for transmission to the MSFN consists of analog and digital signals obtained from the guidance and navigation system, central timing equipment, instrumentation sensors and transducers located throughout the S/C structure and operational systems, and biomedical sensors worn by

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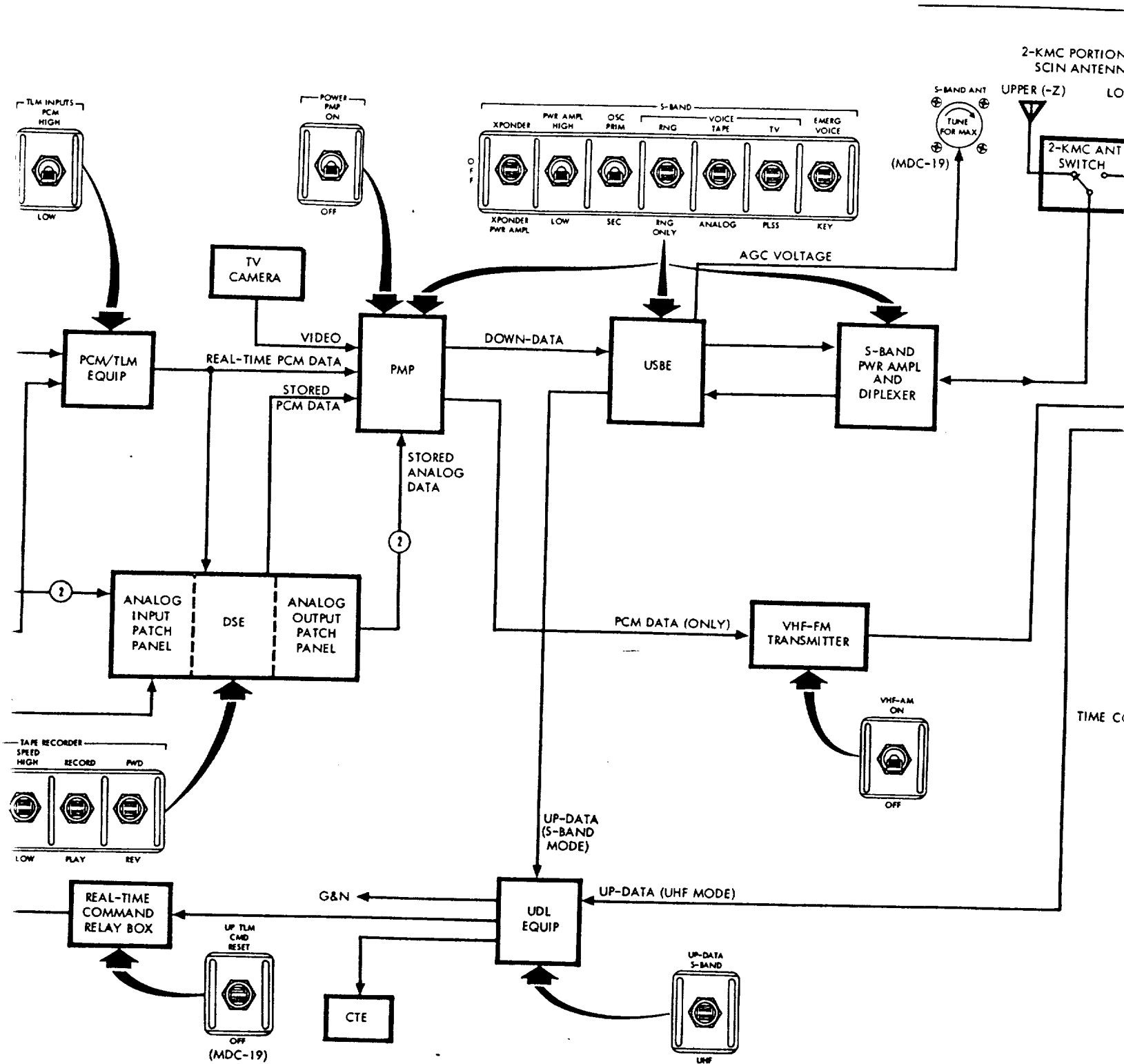
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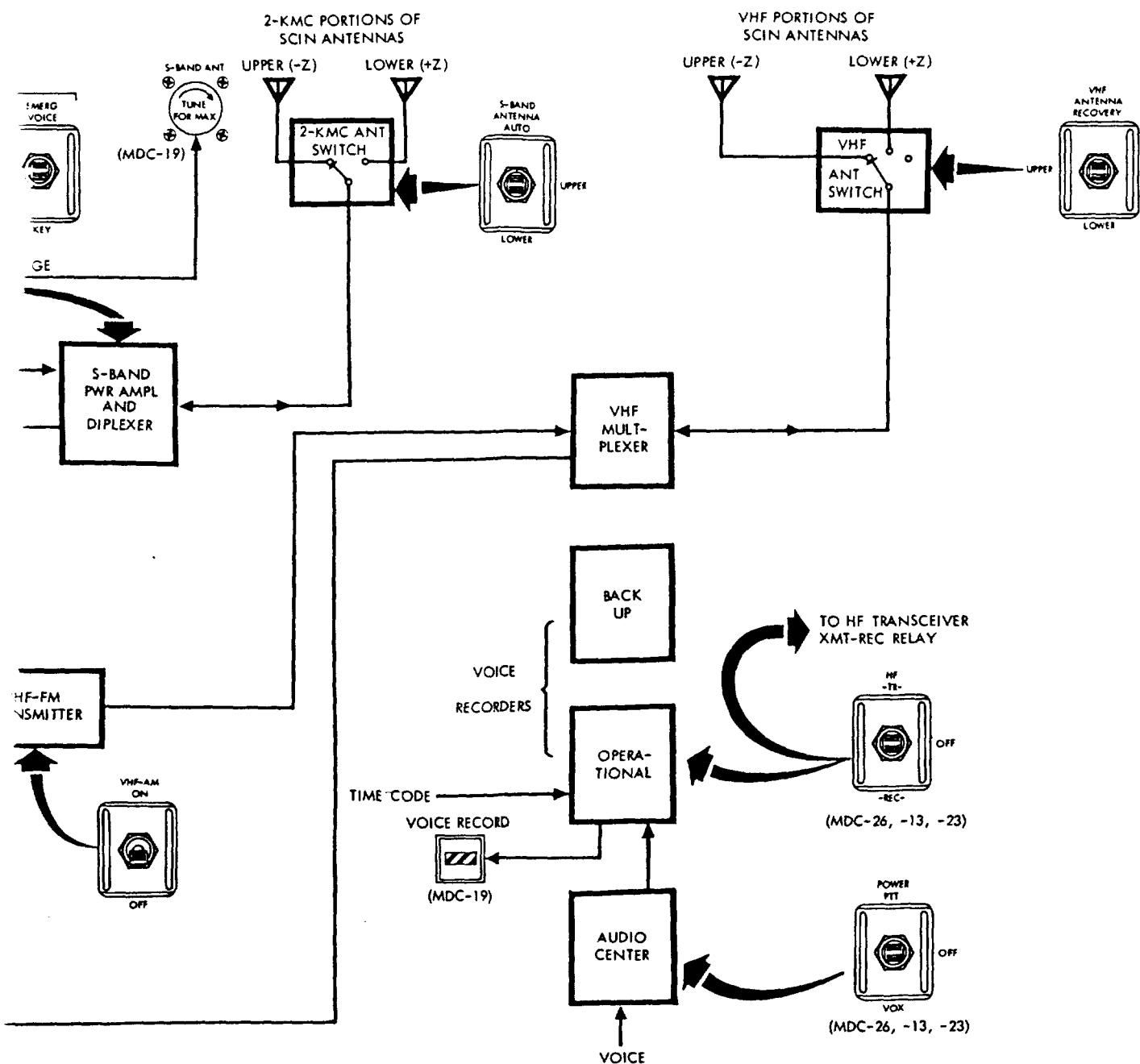


ROLLOUT FRAME 2

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NOTES: 1. All switches shown are on MDC-20 unless otherwise indicated.

2. Not scheduled for use on SC 012 and SC 014.

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Figure 2.8-2. Data Operations

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ROLLOUT FRAME 3



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2.8.3.1 Instrumentation Equipment Group.

The S/C instrumentation equipment consists of various types of sensors and transducers for providing environmental, operational status, and performance measurements of the S/C structure, operational systems, and experimental equipment. The outputs from these sensors and transducers are conditioned to signals suitable for utilization by the S/C displays, presentation to the PCM TLM equipment, or both. In addition, various digital signals are presented to the PCM TLM equipment, including event information, guidance and navigation data, and a time signal from the CTE.

Many of the signals emanating from the instrumentation sensors are of forms or levels which are unsuitable for use by the S/C displays or PCM TLM equipment. Signal conditioners are used to convert these signals to forms and levels which can be utilized. Some signals are conditioned at or near the sensor by individual conditioners located throughout the S/C. Other signals are fed to the signal conditioning equipment (SCE), a single electronics package located in the lower equipment bay. (Refer to signal conditioning equipment in the Voice and Data Equipment Group.) In addition to conditioning many of the signals, the SCE also supplies 5-vdc excitation power to some sensors. The SCE can be turned on or off with the POWER-SCE switch on MDC-20. This is the only control that the crew can exercise over instrumentation equipment for operational and flight qualification measurements. These two instrumentation groups are discussed in the following two paragraphs. Information on scientific and special instrumentation can be found in section 4 of this manual, Experiments and Scientific Equipment.

2.8.3.1.1 Operational Instrumentation.

Operational measurements are those which are normally required for a routine mission and include three categories: in-flight management of the S/C, mission evaluation and system performance, and preflight check-out of the S/C. The operational instrumentation sensors and transducers are capable of making the following types of measurements: pressure, temperature, flow attitude, rate, quantity, angular position, current, voltage, frequency, RF power, and "on-off" type events.

2.8.3.1.2 Flight Qualification Instrumentation.

Flight qualification measurements are those which will vary on different S/C, depending on mission objectives and state of hardware development. Most of them will be pulse-code modulated along with the operational measurements and transmitted to the MSFN. Other flight qualification measurements will be stored in the FQR for postflight analysis only.

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measuring the time lapse between transmission of the signal and reception of the response signal the MSFN can accurately determine the S/C range. Once established, this value can then be continually updated by measuring the doppler shift in the S-band carrier. A ranging mode can be selected again at later times, to verify or up-date the doppler data.

2.8.3 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

To facilitate this presentation, the equipment comprising the T/C system (figure 2.8-4) has been divided into four groups designated as instrumentation equipment, voice and data equipment, RF electronics equipment, and antenna equipment. Specifically, these equipment groups contain the following:

Instrumentation equipment group

- Operational instrumentation
- Flight qualification instrumentation

Voice and data equipment group

- Audio center (A/C) equipment
- Signal conditioning equipment (SCE)
- Pulse-code modulation-telemetry (PCM TLM) equipment
- Television (TV) equipment
- Premodulation processor (PMP) equipment
- Data storage equipment (DSE)
- Flight qualification recorder (FQR) equipment
- Up-data link (UDL) equipment
- Central timing equipment (CTE)
- Voice recorder

RF electronics equipment group

- VHF/AM transmitter-receiver equipment
- HF transceiver equipment
- VHF/FM transmitter equipment
- Unified S-band equipment (USBE)
- S-band power amplifier equipment
- C-band transponder equipment
- VHF recovery beacon equipment

Antenna equipment group

- VHF/2-KMC omni-antenna equipment
- HF antenna equipment
- VHF recovery antenna equipment
- C-band beacon antenna equipment



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After touchdown, the HF recovery antenna must be deployed by setting the POSTLANDING - ANTENNA switches (MDC-25) to DEPLOY A and B while the MASTER EVENT SEQ CONT switches (MDC-24) are at PYRO ARM 1 and 2. HF beacon transmission at a preassigned frequency of 10.006 mc is accomplished by placing the RECOVERY - HF switch (MDC-20) to ON and the RECOVERY - HF-SSB/BCN/AM switch to BCN.

The GFAE survival transceiver (part of the crew's personal equipment) can also be operated in a beacon mode. If used inside the S/C, one of the VHF recovery antennas (No. 1 or No. 2) can be used by manually connecting it to the applicable coax connector on MDC-9.

The VHF antennas and communications equipment condition, as determined by the crew during the postlanding pre-recovery period, will decide the utilization of the coaxial cable connectors located on MDC-9. The connectors are identical and the recovery equipment coaxial cables may be interchanged to provide the most beneficial tracking configuration.

2.8.2.4 Unified S-Band Operations.

2.8.2.4.1 General.

The USBS is primarily designed to be used as a deep-space communications link between the S/C and the MSFN. Nevertheless, on mission 205 some of its capabilities will be tested and it may be called upon for use as backup equipment for voice communications, PCM data transmission, up-data reception, or S/C tracking and ranging when the S/C is within range of a MSFN station equipped for S-band operations. In addition, only the USBS is capable of transmitting TV.

The USBS consists of the S-band transmitter and receiver combined in a single electronic package called the unified S-band equipment (USBE) and the S-band power amplifier (PA). The function of the S-band PA is to provide additional power amplification of the USBE transmitter output. Two levels of amplification (high and low) are possible. A bypass mode is also possible wherein the S-band PA is turned off and the output of the USBE transmitter is sent to the S-band antenna equipment "as is." The 2-kmc portions of the upper and lower SCIN antennas are used for transmission and reception of S-band signals. Antenna selection is made by placing the S-BAND ANTENNA switch (MDC-20) to UPPER, LOWER, or AUTO. In the AUTO position, the antenna will be automatically switched if the signal falls below a minimum threshold.

The PMP is controlled in conjunction with the USBE by the S-BAND switches to provide the proper voice and data inputs to the USBE in accordance with the S-band mode selected.

When operating in a ranging mode, the MSFN can transmit a "coded" pseudo-random noise (PRN) pulse to the S/C via the S-band carrier. The S/C USBE will respond by transmitting an identical pulse to the MSFN. By

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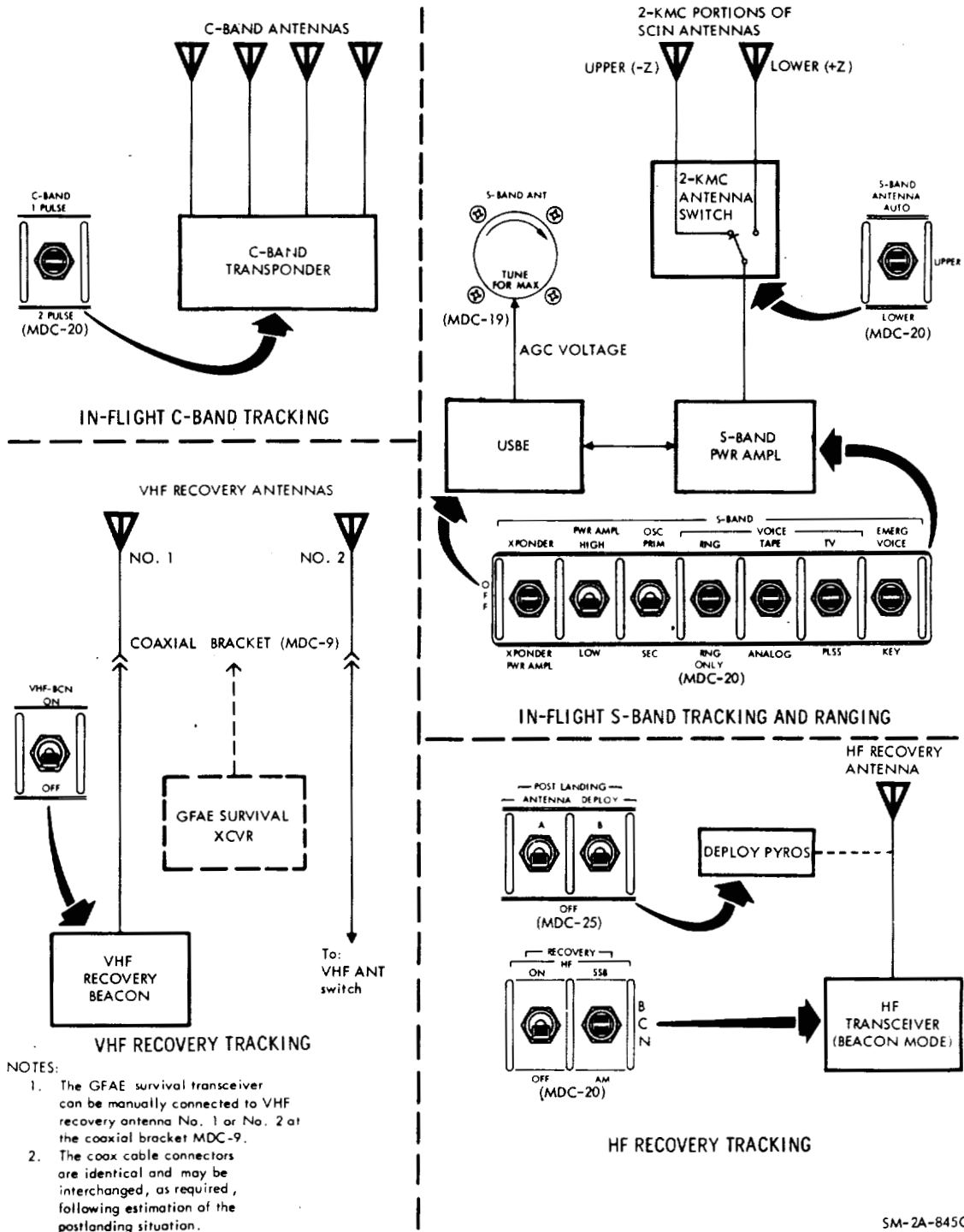


Figure 2.8-3. Tracking and Ranging

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timing data for up-dating the central timing equipment (CTE), and realtime commands (RTCs) for providing the MSFN with limited control of certain on-board functions.

During normal operations, up-data is received by the UHF/FM receiver contained in the up-data link (UDL) equipment. Once received, the signal is processed and decoded, and the information is routed to the G&N system, the CTE, or UDL-RTC relay box. For backup, up-data can also be transmitted by MSFN stations to the S/C via the S-band carrier. When this occurs, the up-data is received by the USBE receiver which extracts the up-data subcarrier and routes it to the PMP where the intelligence is removed from the signal and sent to UDL equipment for processing, decoding, and distribution. In this S-band mode, the UHF/FM receiver is bypassed. Selection of the UHF or S-BAND mode is made with the UP-DATA switch on MDC-20. The UP TLM CMD - RESET/OFF switch (MDC-19) enables the crew to nullify previous RTCs and return control to the S/C. An UP TLM - ACCEPT/BLOCK switch (MDC-14) is also provided so that G&N up-data can be prevented from effecting the computer and the attendant validity signal being sent to the PCM format.

2.8.2.3 Tracking and Ranging.

2.8.2.3.1 In-Flight Tracking and Ranging.

The function of the in-flight tracking and ranging equipment (figure 2.8-3) is to assist the MSFN in determining S/C position and velocity. The primary method employed is C-band tracking. The C-band transponder on-board the S/C is used for this purpose. It operates in conjunction with conventional, earth-based, radar equipment by transmitting response pulses to the MSFN when radar pulses from the earth are received. It operates in a "1-pulse" or a "2-pulse" mode, depending on the type of radar equipment being used at the nearest MSFN station. A single control, the C-BAND switch on MDC-20, is used to activate the C-band transponder in either mode.

Backup tracking and ranging capabilities are provided by the USBS.

2.8.2.3.2 Recovery Tracking.

Line-of-sight and beyond-line-of-sight beacon transmission capabilities are provided to assist recovery personnel in locating the S/C during parachute descent and after touchdown. Line-of-sight beacon transmission is accomplished using the VHF recovery beacon equipment. The beyond-line-of-sight capability is furnished by operating the HF transceiver in a beacon mode.

During parachute descent the VHF recovery beacon is activated by setting the RECOVERY - VHF-BCN switch (MDC-20) to ON. This causes a 2-second, modulated VHF pulse to be transmitted every 5 seconds from VHF recovery antenna No. 1, which is deployed automatically with VHF recovery antenna No. 2 when the main parachutes are deployed.

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the crewman. Some of the instrumentation signals require conditioning before they can be utilized. This is accomplished by the signal conditioning equipment (SCE) activated by the POWER-SCE switch on MDC-20. The remaining TLM signals are either conditioned at their source by local signal conditioners, which requires no action on the part of crewmen, or do not need conditioning. The operational instrumentation signals are used for S/C displays and real time or delayed TLM transmission via VHF-FM and/or S-band. Those to be telemetered are routed to the pulse-code modulation-telemetry (PCM TLM) equipment. Most of the flight qualification signals are routed to the PCM TLM equipment along with the operational TLM signals. A few, however, are recorded as analog signals in the flight qualification recorder (FQR) for postflight analysis only. The FQR will be activated at brief intervals only during critical phases of the mission by the FLIGHT QUAL RCDR switch on MDC-19.

The PCM TLM equipment combines the signals to be telemetered and converts them to a single, digital, pulse train which is then fed to the pre-modulation processor equipment (PMP) and the data storage equipment (DSE). The PCM TLM equipment is activated at all times. Its only control is the TLM INPUTS - PCM switch on MDC-20. This switch is used to select the PCM bit-rate. In the HIGH (51.2 KBPS) position, all TLM inputs to the PCM TLM equipment are processed and combined into the output signal. The LOW (1.6 KBPS) position eliminates the less essential parameters and is used only when a PCM pulse train of reduced bandwidth is required. The reduced bandwidth allows PCM data to be recorded at a reduced (3.75 ips) speed when long periods of data recording are required.

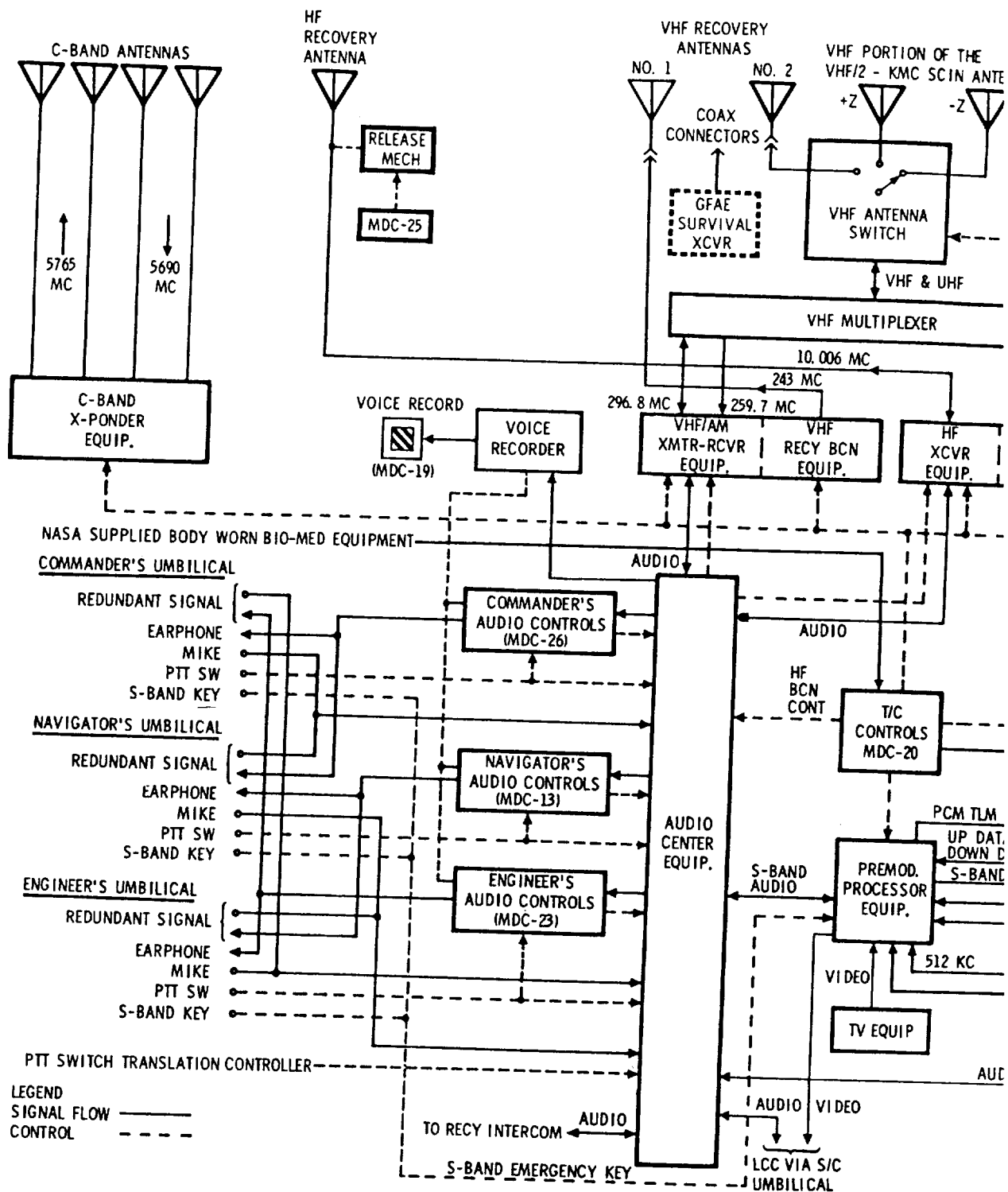
The PCM signal is fed to the PMP and DSE simultaneously, for real-time (R/T) transmission and/or storage. For R/T transmission, the signal is processed through the PMP to the VHF/FM and/or S-BAND transmitters. The PMP is controlled by the POWER - PMP switch, the S-BAND group of switches, and the TAPE RECORDER - PLAY switch. When R/T transmission is not possible, the PCM data can be stored in the DSE, which is controlled by the TAPE RECORDER group of switches and the TLM INPUTS - PCM switch discussed in the previous paragraph. When played back later, the stored PCM data is also processed through the PMP to the VHF/FM and/or S-BAND transmitters for transmission. The sole function of the VHF/FM transmitter is the transmission of R/T or stored PCM data. Its only control is the VHF-FM - ON/OFF switch on MDC-20. It utilizes the same antennas as the VHF/AM transmitter-receiver, namely, the upper or lower SCIN antenna as selected by the VHF antenna switch.

Backup capability for the transmission of PCM TLM data is provided by the USBS. (Refer to a subsequent discussion of unified S-band operations.)

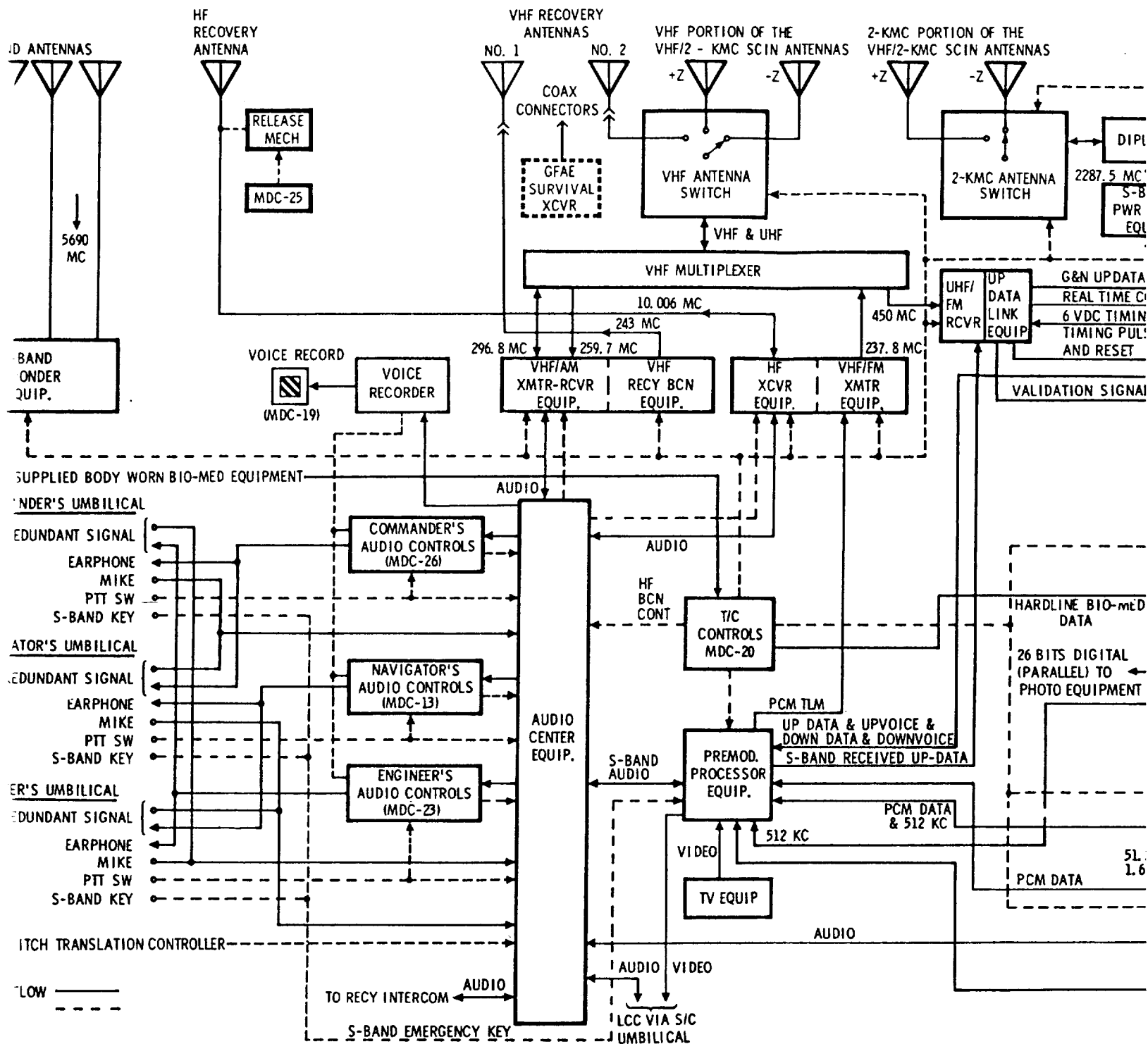
2.8.2.2.3 Up-Data Reception.

Up-data which can be transmitted to the S/C by the MSFN consists of three types: G&N data for up-dating the Apollo guidance computer,

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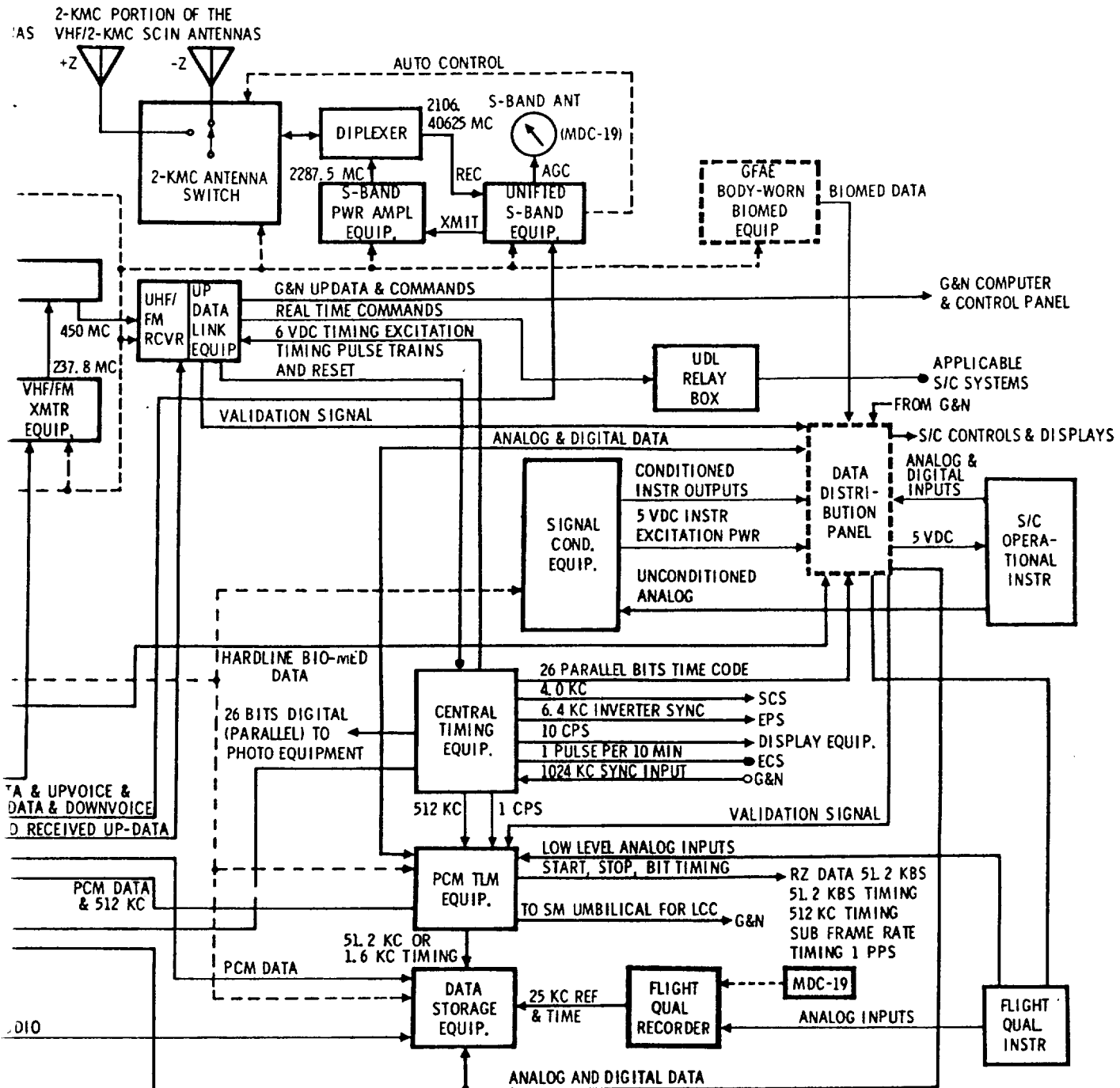






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Figure 2.8-4. Telecommunications System

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2.8.3.2      Voice and Data Equipment Group.

2.8.3.2.1    Audio Center (A/C) Equipment.

The A/C equipment (figure 2.8-5) consists of three separate identical modules located in a single electronics package in the lower equipment bay. Each module is controlled independently by its own control panel and supplied with 28-vdc power through separate circuit breakers. The three control panels, MDC-26, -13, and -23, are located in stations 1, 2, and 3, respectively. Each of the astronaut's headsets, containing two microphones and two microphone amplifiers, and two independently operating earphones, is connected to one of the A/C modules by a cobra cable. Thus each astronaut has a separate headset, audio center module, and audio control panel to provide him with individual control of voice transmission and reception.

Each A/C module contains a microphone amplifier, VOX circuitry, an earphone amplifier, and various signal attenuation, switching, and isolation circuits. The earphone and microphone amplifiers amplify the voice signals to and from the headset. The VOX circuitry is a voice-operated keying circuit that supplies a ground return path necessary for activating the microphone amplifier and the transmitter keying relays in the HF transceiver, intercommunication system, and the power control relay in the operating voice recorder.

Audio signals are provided to and from the HF transceiver equipment, VHF/AM transmitter-receiver equipment, USBE (via the PMP), and the intercom bus. The intercom bus is common to all three modules and provides for the hardline communications between crewmen and with the LCC and recovery forces.

Inputs and outputs are controlled by the RCDR/HF, VHF/AM, S-BAND, and INTERCOM switches on the audio control panels. Each of these switches has three positions: T/R, OFF, and REC. Setting any of the switches to T/R (except S-BAND) permits transmission and reception of voice signals over its respective equipment. REC permits reception only, and OFF disables the input and the output. The operation of the microphone amplifier in each module is controlled by the VOX keying circuit or the PTT pushbutton on the cobra cable or the translation controller. The VOX circuit is energized by the position of the POWER - PTT/OFF/VOX switch on each audio control panel. The PTT position permits monitoring and activation of the microphone amplifier, voice recorder HF, VHF/AM and S-band voice transmission circuits by the PTT key. The VOX position permits all the functions of the PTT position plus VOX activation of the microphone amplifier, voice recorder and HF transmitter.

Three potentiometer controls are also provided on each audio control panel: VOX SENS, INTERCOM BALANCE, and VOLUME. The VOX SENS control is used to adjust the sensitivity of the VOX circuitry, determining the amplitude of the voice signal necessary to trigger the VOX keying

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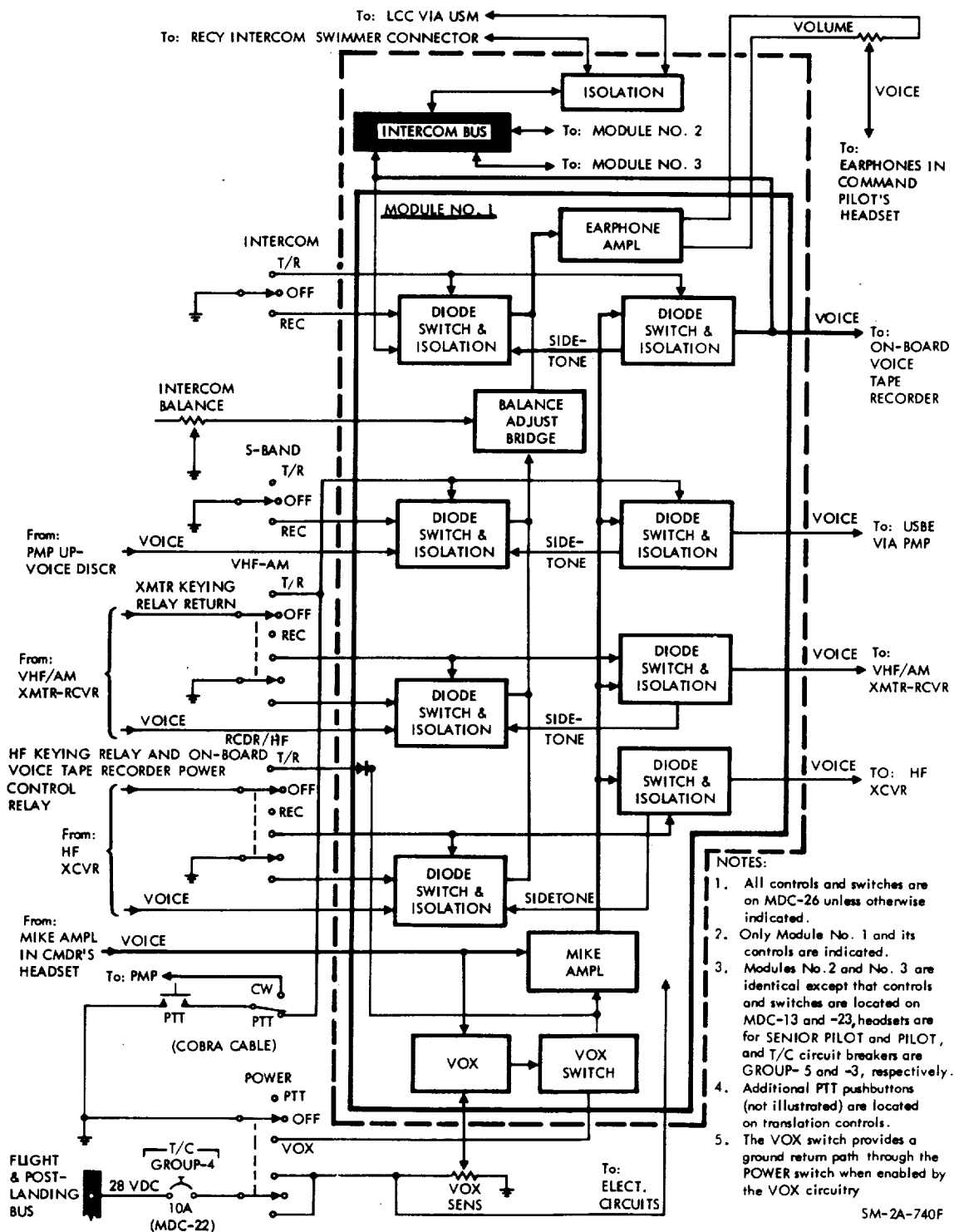


Figure 2.8-5. Audio Center Equipment

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circuit. The INTERCOM BALANCE control adjusts the level of voice signal inputs from the RF equipment relative to the level of voice signal inputs from the intercom bus. The VOLUME control adjusts the output of the earphone amplifier.

2.8.3.2.2 Signal-Conditioning Equipment (SCE).

The signal-conditioning equipment (SCE) is contained in a single electronics package located in the LEB. (See figure 2.8-6.) Its functions are to convert various kinds of unconditioned signals from the instrumentation equipment into compatible, 0- to 5-volt d-c analog signals, and to provide excitation voltages to some of the instrumentation sensors and transducers.

The SCE uses the following module types: The active attenuator, to attenuate high-signal voltages; the ac-(am) to-dc converter, to detect the amplitude variations of an a-c signal; the dc differential amplifier, to amplify small signals; the dc differential bridge amplifier, to detect resistance changes; the bi-phase demodulator, to convert S/C position resolver outputs; the frequency demodulator, to detect frequency changes in an a-c signal; and the power supply, to provide +20 volts and -20 volts to the SCE circuitry, 10 volts as bridge excitation, and 5 volts to excite other S/C sensors.

The conditioned output signals from the SCE are routed to the data distribution panel (DDP). The DDP provides parallel outputs, where necessary, and routes the signals to the PCM telemetry equipment, S/C displays, and GSE connections.

The only external control for the SCE is the two-position POWER—SCE toggle switch on MDC-20. Placing this switch to ON applies 28 volts dc to the latch winding of the latching relay, which closes contacts applying 3-phase a-c power to the power supply module. In the OFF position, the relay is unlatched, removing a-c power from the power supply.

2.8.3.2.3 Pulse-Code Modulation Telemetry (PCM TLM) Equipment.

The function of the PCM TLM equipment (figure 2.8-7) is to convert TLM data inputs from various sources into one serial digital output signal. This single output signal is routed to the PMP for transmission to the MSFN or to the DSE for storage. The PCM TLM equipment is contained in two separate units located in the lower equipment bay: PCM unit 1 and PCM unit 2.

Input signals to the PCM TLM equipment are of four general types: low-level analog, high-level analog, parallel digital, and serial digital. Some of the low-level analog inputs are supplied directly from the instrumentation sensors; other data inputs are routed through the data distribution panel (DDP).

Two modes of operation are possible: the high- (normal) bit-rate mode of 51.2 kilobits per second (KBS) and the low- (reduced) bit-rate mode of 1.6 KBS. Operational mode is selected by placing the TLM INPUTS—PCM switch on MDC-20 to HIGH or LOW, as applicable. When the switch is in the LOW position, the high PCM bit-rate can be commanded by the MSFN via the UDL equipment.

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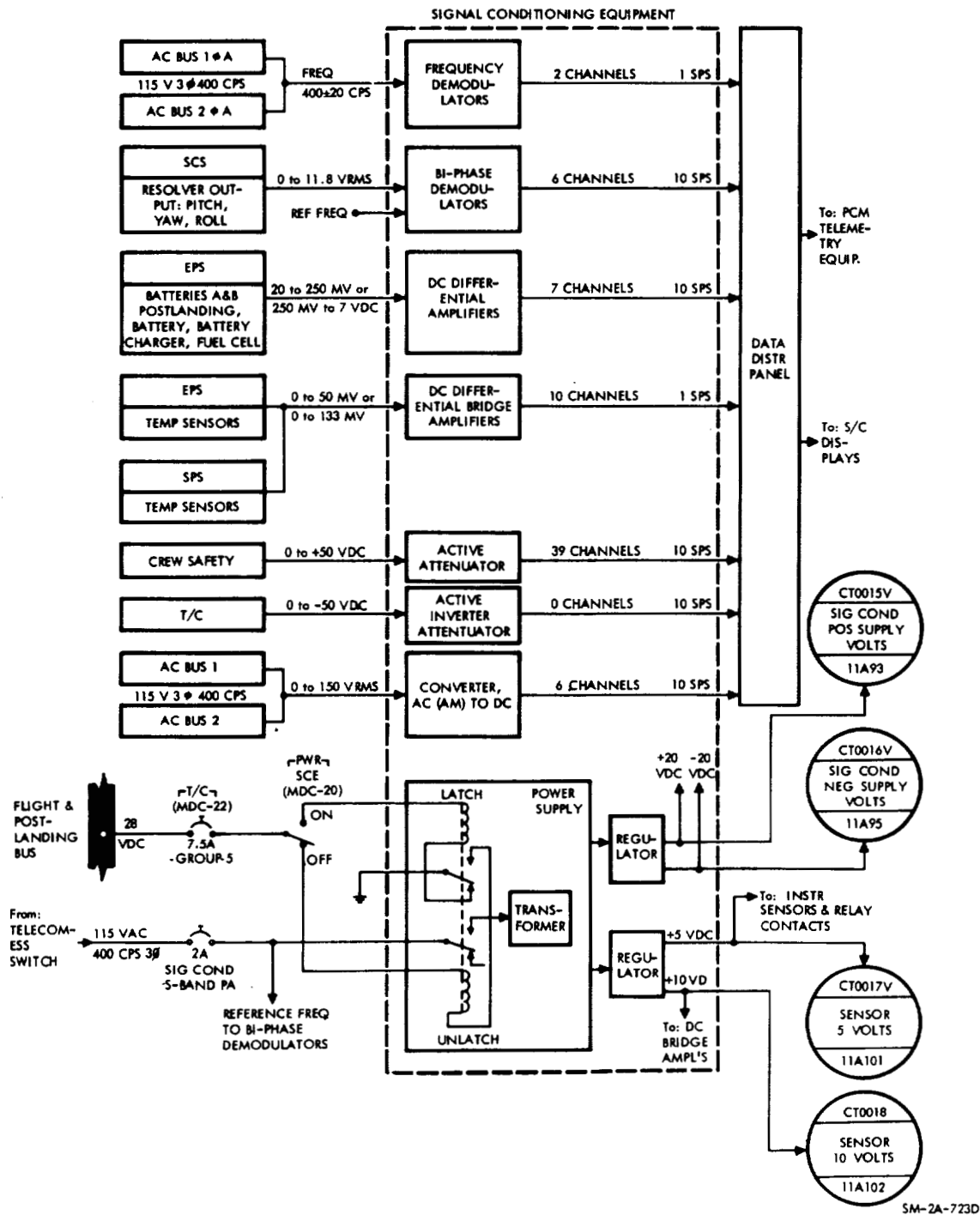


Figure 2.8-6. Signal Conditioning Equipment

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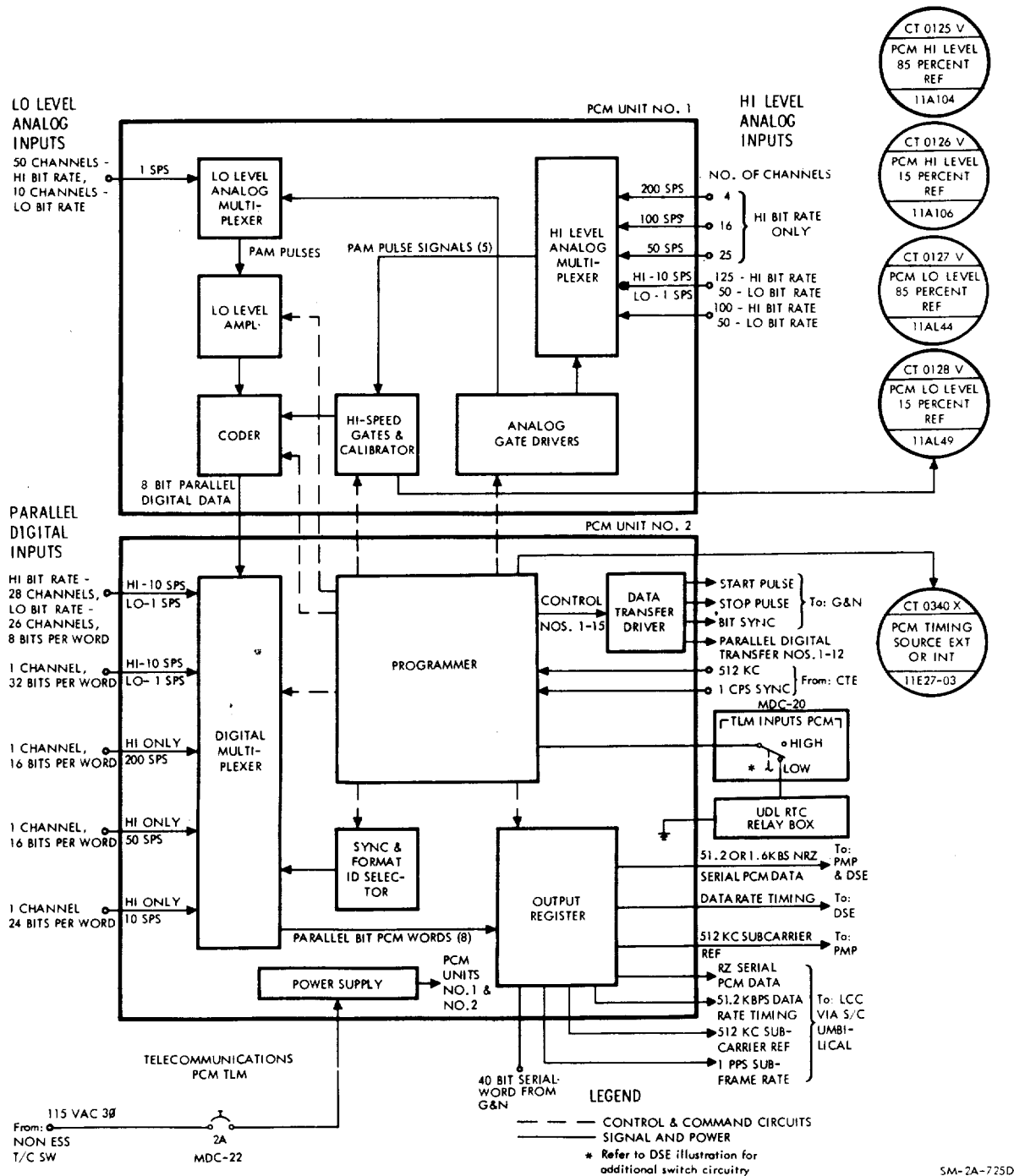


Figure 2.8-7. Pulse Code Modulation Telemetry

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2.8.3.2.4      Television (TV) Equipment.

The TV equipment consists of a small, portable, TV camera (figure 2.8-8) that can be hand-held or mounted in one of four locations in the command module. Its function is to acquire real-time video information for transmission to the MSFN during S-band testing.

The first camera mounting position is located below the main display console, and will permit a front view of the crew lying in their couches. The second position is located behind the head of the center seat, and will permit viewing of crew activities in the middle of the command module. The second position is also provided with a five-foot stretch cable to permit hand-held use of the camera for coverage of any desirable target inside or outside the S/C. The third position is located in the right-hand equipment bay, and permits viewing of astronauts at work in that area. The final position utilizes a special bracket which allows the TV camera to look out the right-hand docking window.

The TV camera is connected directly to the PWR cable at the first mounting position. If the TV camera is to be used in the mounting position behind the center couch, the PWR cable must be connected to the connector marked "TV Cam to Hatch J107," and the camera, in turn, should be connected to the connector at that position (J191), by the stretch cable. If the TV camera is to be mounted by the right-hand equipment bay, the PWR cable must be connected to the connector marked "TV Cam to RHEB," and the TV camera connected to the connector at that location (J195) by the stretch cable.

The TV camera is constructed with a pistol-grip type of handle on the bottom, which can be extended to facilitate portable use. The TV camera is fitted with a fixed-focus wide-angle lens for picture taking within the command module. For taking pictures of the earth or moon through the C/M window, an interchangeable zoom lens is provided. The zoom lens has a look angle of from 9 degrees through 30 degrees. It is fitted with a through-the-lens type viewer that will enable the operator to see the change in field of view and relative size of the scene while the lens is adjusted. The electronic circuitry in the camera is equipped with an automatic gain control to allow for differences in target illumination.

The TV camera is activated by a slide switch in the pistol-grip handle, which applies 28 volts dc to the camera power supply when set to on. This energizes the entire camera and results in a video output signal that is fed to the PMP. In the PMP, the video signal is frequency multiplexed with the telemetry data and voice, which is transmitted to earth via the USBE. The USBE must be operating in a TV mode to permit this transmission. An AUTO LIGHT CONTROL switch has been added to the camera, permitting it to compensate for either peak or average scene illuminations from 0.1 to 30 foot candles.

2.8.3.2.5      Premodulation Processor (PMP) Equipment.

The PMP equipment (figure 2.8-9) functions as a data processing and distribution center providing necessary interface, where required, between the voice, data, and RF equipment. The PMP consists of ten modules mounted in a single electronics package located in the lower equipment bay. These modules contain filters, oscillators, modulators, demodulators, detectors, switching circuits, discriminators, mixing and keying networks, and a power supply.

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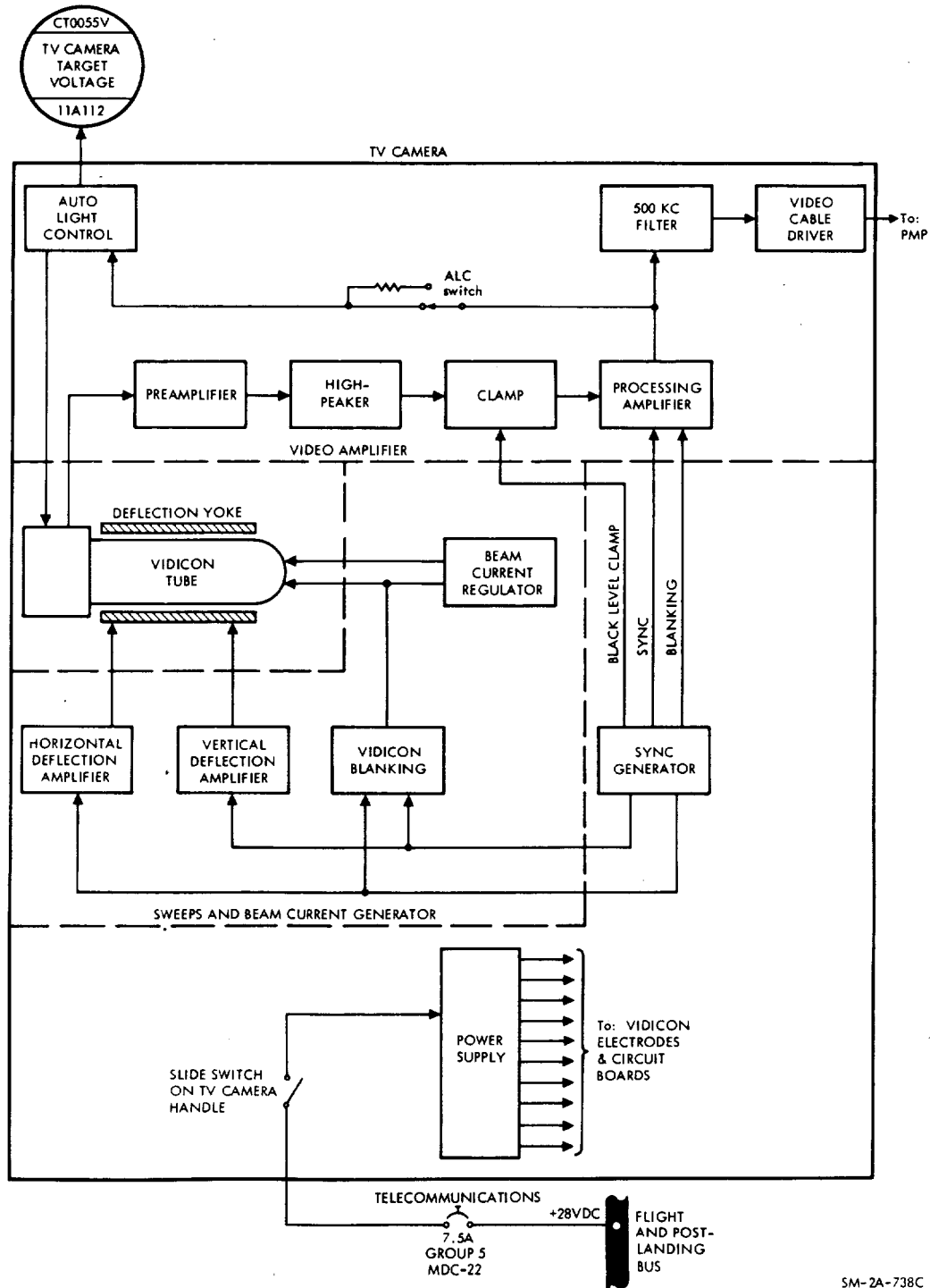


Figure 2.8-8. Television Equipment

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The PMP can operate in many possible modes. All of the external controls for the PMP are switches located on MDC-20. The switches which affect the PMP consist of the POWER - PMP switch, the S-BAND - VOICE group of switches, the S-BAND - EMERG switch, and the TAPE RECORDER - PLAY and - RECORD/PLAY switches. Also, during emergency key operation, the PTT keys on the cobra cables and translation controls, control the PMP emergency key network. All of the signal inputs available to the PMP are listed in the PMP INPUTS table at the end of this paragraph. PMP outputs are dependent upon switch configuration. The PMP OUTPUTS table, also at the end of this paragraph, shows the various composite output signal possibilities along with their destinations and the switch positions required for any mode of operation. It should be noted that the S-BAND and TAPE RECORDER switches also affect the operational mode of the USBE and DSE.

One function of the PMP is to process the PCM TLM signal obtained from the PCM TLM equipment or DSE and route it to the VHF/FM transmitter equipment for transmission to the MSFN. This output will be provided whenever a PCM input is available, regardless of mode and simultaneously with other PMP outputs.

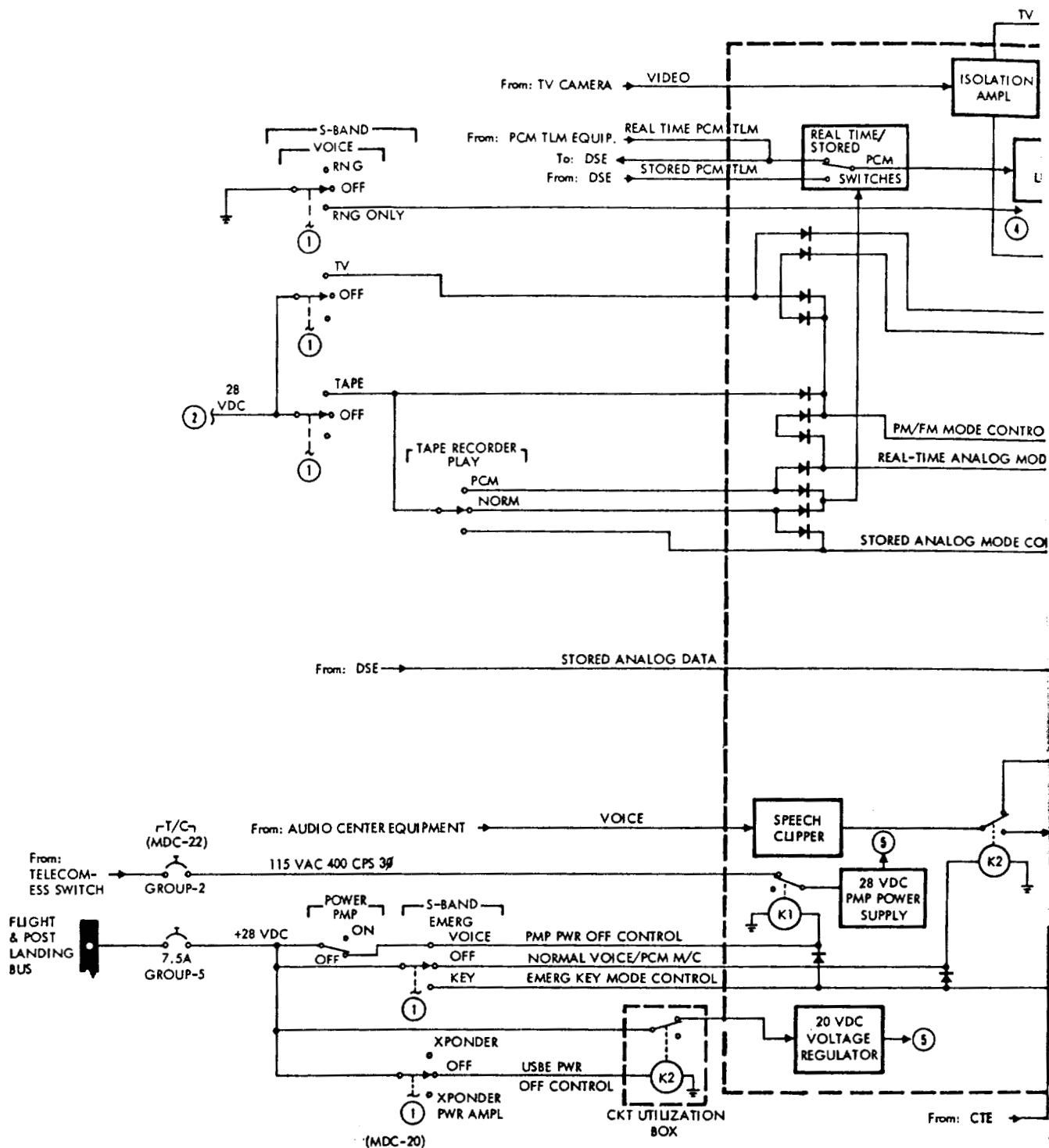
All remaining PMP functions involve interface with the USBE. Inputs to the PMP from the USBE are the 70-kc up-data and 30-kc up-voice sub-carriers. These are fed into the up-data and up-voice discriminator circuits. These two circuits (as well as circuitry needed for emergency S-band modes) do not require the PWR-PMP switch to be on. They are supplied with power independently whenever the USBE is in operation. Outputs from the up-data and up-voice discriminators are fed to the UDL and A/C equipment, respectively.

The PMP supplies an output to one of the three USBE inputs, depending on S-band mode as selected by the S-BAND - VOICE group of switches and the S-BAND - EMERG switch. The USBE inputs are designated PM, FM-1, and FM-2. During normal S-band modes, the PMP supplies either a PM or FM-1 output to the USBE. The PM output supplies real-time PCM TLM and voice to the USBE when the USBE is operating in a normal voice or a ranging mode. If the USBE ranging only mode is selected, the PCM TLM portion of the output is eliminated, leaving only voice signals in the PM-1 output. When recorded data or TV data is to be transmitted along with PCM TLM and voice data, the FM-1 output is supplied to the USBE. This mode permits the greater bandwidth which is required for transmission of this data.

There are two emergency modes; emergency voice and emergency key, selected by the S-BAND - EMERG switch and used to permit emergency transmission of voice or code over the USBE with the PMP shutdown. With the S-BAND - EMERG switch in the center (OFF) position, the PWR - PMP switch controls the application of power to the PMP. However, with the S-BAND - EMERG switch set to either VOICE or KEY, a-c power is removed from the PMP. In the KEY position, a separate 28-volt d-c

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**WOLDOUT FRAME /**



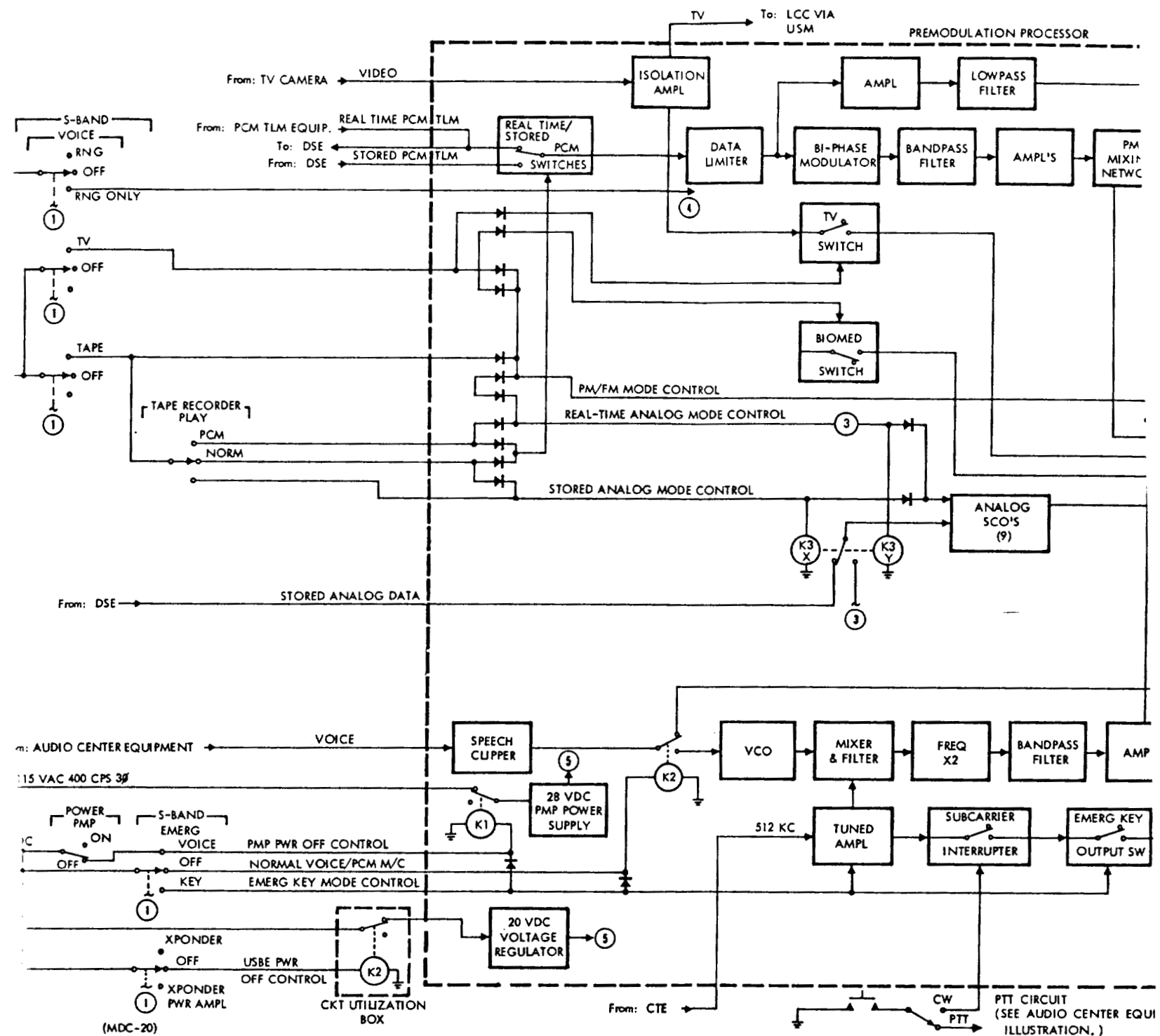


Figure 2.8-9.

ROLDOUT FRAME 2

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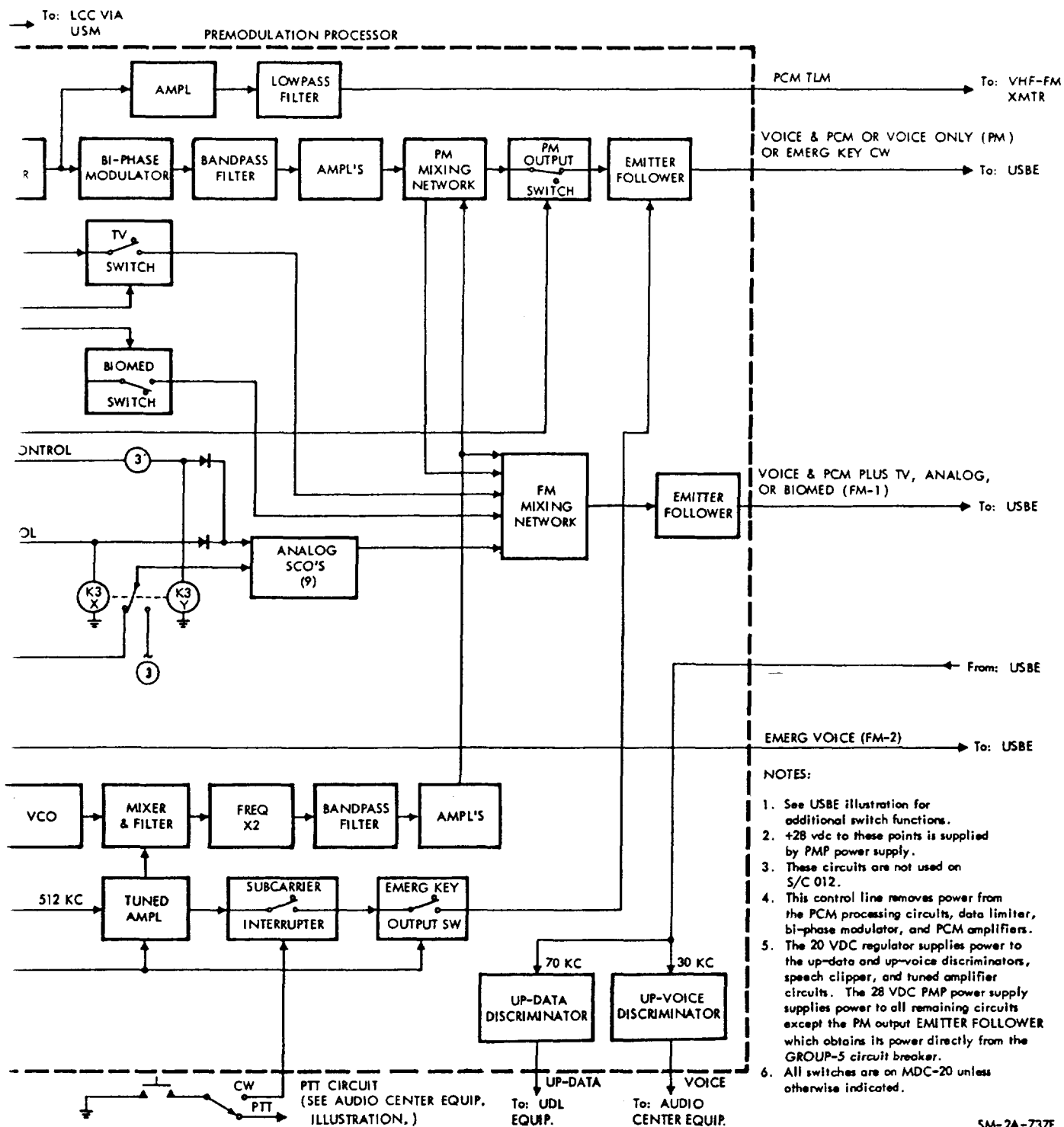


Figure 2.8-9. Premodulation Processor Equipment

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source is used to enable the emergency key network only, which permits a 512-kc signal from the CTE to be keyed by the PTT key in the cobra cable. This signal is applied to the PM input of the USBE. In the VOICE position, voice signals from the audio center equipment are routed directly through the PMP and supplied to the FM-2 (emergency voice) input of the USBE.

The following matrix shows the switching configurations of the S-band system in several operational modes.

PMP Inputs		
Signal Type	Source	Application
Real-time PCM TLM	PCM TLM equipment	Transmission to MSFN via USBE or VHF/FM transmitter
Video	TV equipment	Transmission to MSFN via USBE
Voice	Audio center equipment	Transmission to MSFN via USBE
Recorded PCM TLM	DSE	Transmission to MSFN via USBE or VHF/FM transmitter
512-kc square wave	CTE	CW transmission to MSFN during emergency key mode
512-kc square wave	PCM TLM equipment	Subcarrier for transmission of PCM TLM to MSFN via USBE
70-kc up-data subcarrier	USBE	Detection of up-data received from MSFN via USBE
30-kc up-voice subcarrier	USBE	Detection of up-voice received from MSFN via USBE

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PMP Outputs									
Output		Switch Positions (MDC-20)							
Types of Data	Destination	PWR	S-BAND - VOICE Group			S-BAND	TAPE RECORDER		
			RNG-Off-RNG ONLY	TAPE-Off	TV-Off	EMERG	PLAY	RECORD-Off-PLAY	
Real-time voice	USBE (FM-2)	*		*		VOICE	*	*	
Interrupted 512-kc carrier (keyed by PTT switch)	USBE (PM)					KEY			
Real-time PCM TLM	VHF/FM Transmitter	ON	*	Off (center)	*	Off (center)			
Recorded PCM TLM				TAPE			PCM or NORM	PLAY	
Real-time PCM TLM and voice	USBE (PM)		RING or Off (center)	Off (center)	Off (center)		*	RECORD or OFF (center)	
Real-time voice			RNG ONLY						
Recorded PCM and real-time voice	USBE (FM-1)		*	TAPE			NORM	PLAY	
*This switch does not affect this output mode.									

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PMP Outputs									
Output		Switch Positions (MDC-20)							
Types of Data	Destination	PWR	S-BAND - VOICE Group			S-BAND	TAPE RECORDER		
			RNG-Off-RNG ONLY	TAPE-Off	TV-Off	EMERG	PLAY	RECORD-Off-PLAY	
Recorded PCM TLM and real-time voice	USBE (FM-1)	PMP	*	TAPE	Off (center)	Off (center)	PCM	Play	*
Real-time PCM TLM and voice		ON		Off (center)	TV				
Real-time PCM TLM, voice, and TV				Off (center)					
Real-time PCM TLM and voice									
Up-data commands	UDL			*	*				
Up-voice	Audio Center Equipment								
*This switch does affect this output mode.									

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2.8.3.2.6 Data Storage Equipment (DSE).

The DSE (figure 2.8-10) is a three-speed, 14-track magnetic tape recorder and reproducer located in the LEB. It is used to store data during phases of the mission which inhibit or prevent the successful transmission of this data to the MSFN. Data can be recorded in parallel on five digital channels, and played back during a later phase of the mission for transmission to the MSFN. Each reel contains 2250 feet of one-inch-wide, magnetic, Mylar tape.

The PCM TLM data is obtained from the PCM TLM equipment as a single serial pulse train at a high bit-rate of 51.2 KBPS or a low bit-rate of 1.6 KBPS, depending on the PCM TLM mode. In the DSE, a serial-to-parallel converter circuit converts this signal into four parallel digital channels, each of which has a resulting pulse repetition rate (PRR) of only 12.8 KBPS or 0.4 KBPS (one-fourth of the original PRR). The PCM TLM equipment also furnishes a 51.2-kc or 1.6-kc square wave timing signal to the DSE, which is also divided by four. These five signals, the four channels of PCM TLM and the clock signal, are amplified by the five digital record amplifiers and fed to the digital record heads. Only one analog channel, the 25-kc reference and timing signal from the FQR, is scheduled for use on SC012.

During playback, the playback heads pick up the recorded data and present it to the digital playback amplifiers. The four parallel channels of recorded digital data and the clock signal divided by four are picked up by the five digital playback heads and presented to the five digital playback amplifiers. The amplified signals are then routed to the parallel-to-serial converter and the reproduce module. The four digital signals are converted back to a single serial pulse train which is fed to the PMP equipment. The bit-rate of this output will always be 51.2 KBPS, even if the recorded data was originally 1.6 KBPS. This is due to different speeds used in recording and reproducing. The 51.2 KBPS high bit-rate PCM signal is recorded at 15 inches per second (ips) and played back at the same speed. The low bit-rate signal of 1.6 KBPS is recorded at 3.75 ips, however, and played back at 120 ips, an increase of 32 times. This increases the 1.6 KBPS PRR to 51.2 KBPS.

The DSE is a bidirectional machine with a tape transport mechanism capable of forward or reverse operation at any of three speeds: 3.75 ips (low speed), 15 ips (normal speed), and 120 ips (high speed). The low speed of 3.75 ips is used only to record low bit-rate PCM TLM data. The DSE playback electronics is automatically disabled whenever this speed is selected. The normal speed of 15 ips is used to record and play back high bit-rate PCM TLM data. The high speed of 120 ips is used for fast dump of the low bit-rate PCM TLM data which was recorded at 3.75 ips. The high speed is also used for fast forward or reverse rewinding. Maximum operating times, to record or play back the entire 2250 feet of tape, are as follows: 2 hours at the low speed of 3.75 ips, 30 minutes at the normal speed of 15 ips, and 3.75 minutes at the high speed of 120 ips.

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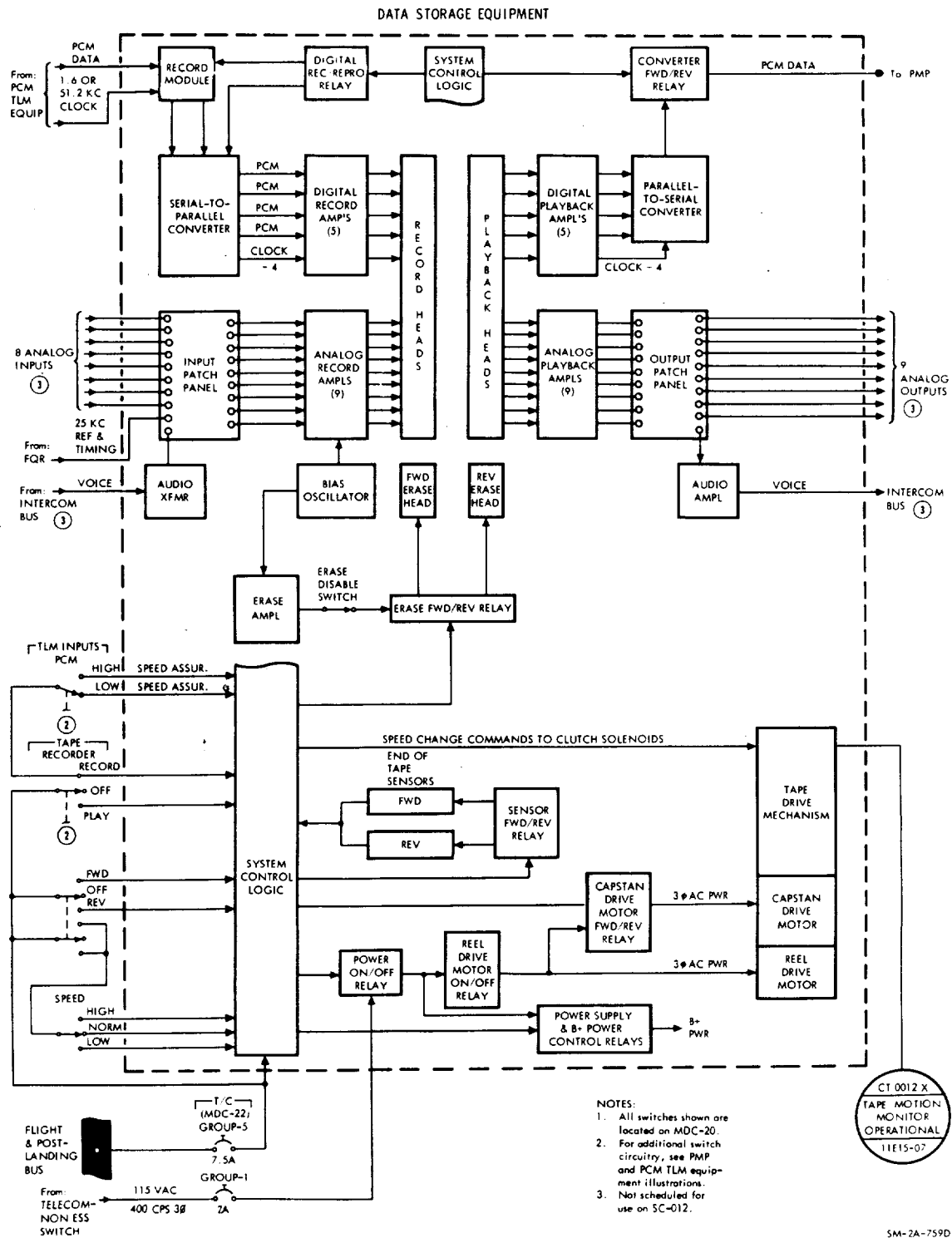


Figure 2.8-10. Data Storage Equipment

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Tape speed and direction are controlled by the TAPE RECORDER - SPEED and - FWD/OFF/REV switches on MDC-20. Other TAPE RECORDER switches are the RECORD/PLAY switch which selects the record or playback mode, and the PLAY switch which selects the type of data to be reproduced. The PLAY switch has two positions: PCM and NORM. In either position, only PCM TLM data is reproduced and routed to the PMP equipment. The S-BAND - VOICE - TAPE switch must be set to TAPE before the TAPE RECORDER - PLAY switch becomes effective. The TLM INPUTS - PCM switch also affects tape recorder operation when recording. The interlock circuit in the DSE system control logic, which prevents selection of conflicting operational modes, locks the tape speed at 15 ips (normal) when the TLM INPUTS - PCM switch is set to HIGH. When set to LOW, the tape speed is locked at 3.75 ips. The proper control switch configuration for all DSE modes is shown in the table at the end of this paragraph.

An end-of-tape sensing circuit in the DSE automatically removes power from the tape drive mechanism and electronic circuits when the end of the tape is reached.

DSE Functions	Switch Positions					
	S-BAND-VOICE	TAPE RECORDER				TLM INPUTS
	TAPE-OFF-ANALOG	PLAY PCM-NORM-ANALOG	SPEED HIGH-NORM-LOW	RECORD-OFF-PLAY	FWD OFF-REV	PCM HIGH-LOW
Record high bit rate	OFF	Any	NORM	RECORD	FWD <sup>o</sup> or REV	HIGH
Record low bit rate	OFF	Any	LOW	RECORD	FWD or REV	LOW
Playback recorded high bit rate	TAPE	PCM or NORM	NORM	PLAY	FWD or REV	Any
Playback recorded low bit rate	TAPE	PCM or NORM	HIGH	PLAY	FWD or REV	Any
Playback recorded <sup>oo</sup> mixed bit rate	TAPE	PCM or NORM	NORM	PLAY	FWD or REV	Any
Reposition tape to end of reel (rewind)	OFF	Any	HIGH	PLAY	FWD or REV	Any
<sup>o</sup> Since the DSE is a bidirectional machine, it can record, play back, or rewind in either direction. <sup>oo</sup> Under present mission procedures, this mode should not be necessary.  Illegal Modes: 1. High bit rate must be recorded at normal speed or tape motion will stop. 2. Low bit rate must be recorded at low speed or tape motion will stop. 3. If tape is played back at low speed, the tape will move, but there will be no play back data available to the transmitters. 4. If tape is played back at high speed and contained high bit rate data, the play back data will be garbled. 5. If a FWD or REV command only is given to initiate a rewind, there will be no tape motion. A mode must also be selected (preferably PLAY) before tape will move.						

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2.8.3.2.7 Flight Qualification Recorder (FQR).

The FQR is a 14-track magnetic tape recorder which is used to record certain flight qualification measurements during critical phases of the mission. (See figure 2.8-11.) This data will be used for postflight analysis only; the FQR has no in-flight playback or transmission capability. It will be activated in a record mode during the ascent and entry phases of the mission and during SPS burns.

Flight qualification data is recorded in analog form. (Digital data cannot be recorded on the FQR.) Two recording tracks (one record head in each of two record-head stacks) are used for reference and time code recording. To accomplish this, an elapsed time code generator is used to modulate a narrow-band VCO. The output of the VCO is then mixed with the output of a 50 kc reference oscillator. This composite signal is presented to each of the two record heads through two direct record amplifiers.

The FQR operates at a record speed of 15 ips and a rewind speed of 120 ips. The 15 ips record speed allows a total of 30 minutes recording time per reel of tape. Because there are no provisions for crewmembers to change tape reels during the mission, the FQR must be used conservatively. Normally, the rewind function will not be used unless it is required to back the tape up to the beginning during prelaunch activities. End-of-tape sensing is provided, which will automatically halt the tape motion and remove power from the electronic circuits when the end of the tape is reached in either direction.

Crewman control of the FQR is provided by the FLIGHT QUAL RCDR, 3-position toggle switch on MDC-19. In the STOP position, all a-c and d-c power is removed. Placing the switch to RECORD activates all electronic circuitry and the tape transport mechanism, which moves the tape forward at 15 ips. The REWIND position activates the tape transport mechanism to move the tape backward at 120 ips.

The measurement numbers and names of the parameters stored in the FQR are presented in the following list. This does not include the two FQR channels utilized for storage of reference and timing code storage.

Measurement Number	Identity
CG 2010 V	X PIPA output, in phase
CG 2030 V	Y PIPA output, in phase
CG 2050 V	Z PIPA output, in phase
CK 0004 A	Linear acceleration structure X axis A
CK 0005 A	Linear acceleration structure Y axis A

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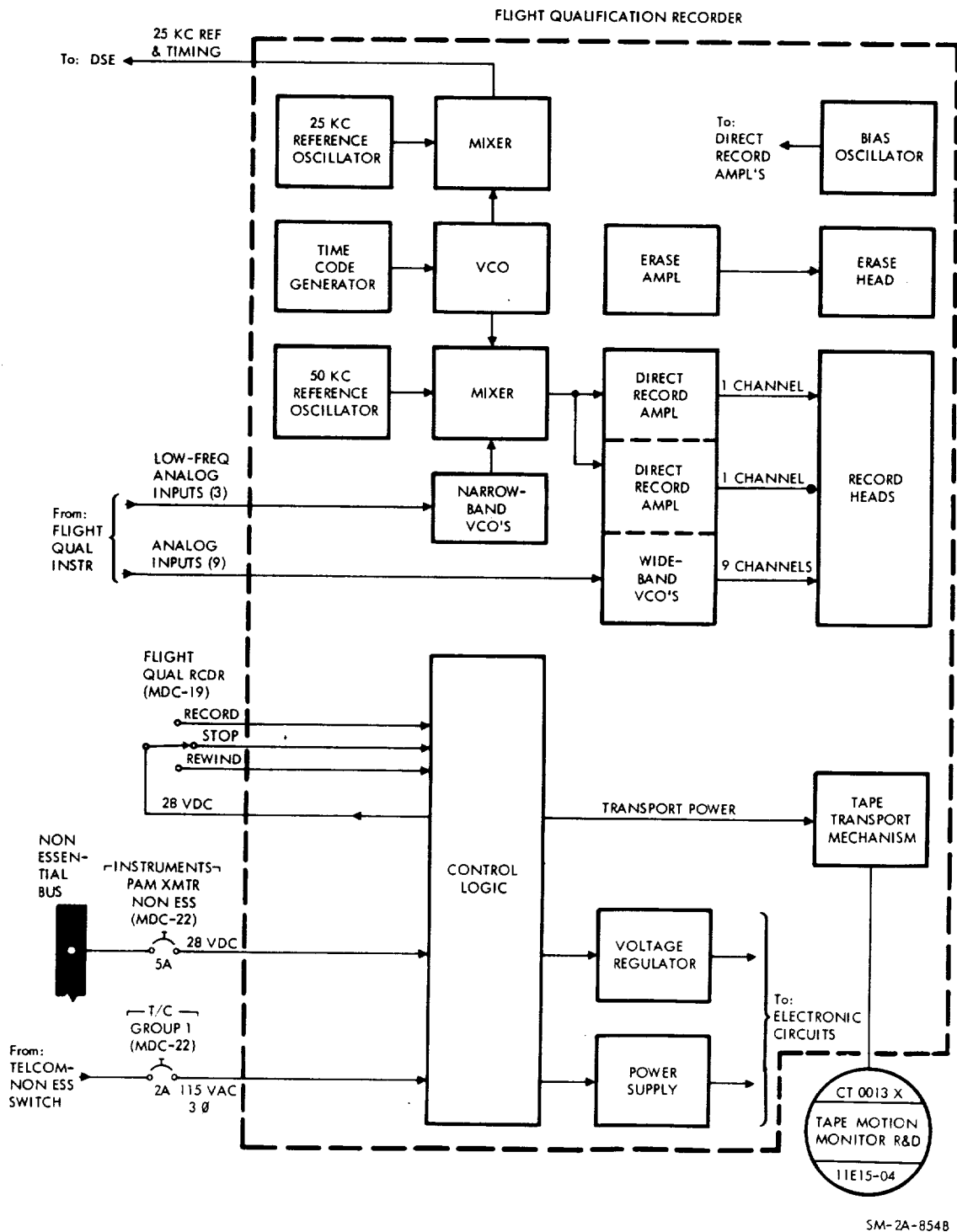


Figure 2.8-11. Flight Qualification Recorder Equipment

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Measurement Number	Identity
CK 0006 A	Linear acceleration structure Z axis A
CR 0514 P	CCW roll engine pressure, system A
CR 0520 P	CCW roll engine pressure, system B
CR 0623 P	Fuel line pressure, system A
CR 0624 P	Fuel line pressure, system B
CR 0625 P	Oxidizer line pressure, system A
CR 0626 P	Oxidizer line pressure, system B

2.8.3.2.8 Up-Data Link (UDL) Equipment.

The function of the UDL equipment is to receive, verify, and distribute digital up-dating information sent to the S/C by the MSFN at various times throughout the mission to up-date or change the status of operational systems. The UDL (figure 2.8-12) consists of a UHF-FM receiver, a transistor mode switch, detecting and decoding circuitry, a buffer storage unit, output relay drivers, and a power supply. The UDL provides the means for MSFN to update the AGC, the CTE, and to select certain vehicle functions.

Two operational modes are possible: UHF and S-band. The mode normally used is UHF. In this mode, the incoming 450-mc up-data carrier is received by the VHF omni-antenna equipment and fed to the UHF receiver in the UDL. The intelligence is detected from the carrier and routed through the mode switch to the sub-bit detector, which converts it to a serial digital signal. The digital output from the sub-bit detector is fed to the remaining UDL circuitry, which stores and checks the digital data, determines the proper destination of the data, and processes it to the appropriate S/C system or equipment.

Real-time commands from the real-time command (RTC) drivers are supplied to the UDL RTC relay box which contains four, RTC, 2-position, latching relays. Thus eight real-time commands are possible: four "set" commands and four "reset" commands. The chart on the following page lists the eight commands by number and function.

The S-band up-data mode can be selected when the USBE is in operation. In this mode, the UHF receiver in the UDL is deactivated and its function is replaced by the USBE receiver and the PMP. Up-data information can be transmitted to the S/C within the 2-kmc S-band signal. When this signal is received by the USBE receiver, the 70-kc subcarrier containing the up-data information is extracted and sent to the up-data discriminator in the PMP. The resulting composite audio frequency signal is routed to the sub-bit detector in the UDL.

There are three external controls for the UDL equipment. One is the three-position, center-off, UP-DATA switch on MDC-20. When set to the

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UDL Real-Time Commands				
Command	Action	UDL Relay	MDC-20 SW Position	Results
00	Deactivates system A abort request light	K1 (RESET)		MDC-3
01	Activates system A abort request light	K1 (SET)		MDC-3 turns on abort light.
02	Effect on C-band equipment operation determined by position of C-band switch on MDC-20	K3 (RESET)	C-BAND 1 PULSE	C-band equipment continues to operate in 1-pulse mode.
			OFF	C-band equipment remains off.
			2 PULSE	C-band equipment continues to operate in 2-pulse mode.
03	Turns C-band equipment on in 2-pulse mode	K3 (SET)	C-BAND 1 PULSE	C-band equipment continues to operate but switches to 2-pulse mode.
			OFF	Energizes C-band equipment which operates in 2-pulse mode.
			2 PULSE	No effect on C-band operation.
04	Effect on VHF-FM transmission of PCM data determined by position of VHF-FM-ON/OFF and TLM INPUTS-HIGH/LOW switches on MDC-20	K4 (RESET)	VHF-FM ON	No effect on VHF-FM transmitter.
			OFF	No effect on VHF-FM transmitter.
			TLM INPUTS PCM HIGH	PCM TLM remains in 51.2 KBS.
			LOW	PCM TLM output is 1.6 KBS.
05	Turns VHF-FM transmitter on and changes bit rate from low to high	K4 (SET)	VHF-FM ON	No effect on VHF-FM transmitter.
			OFF	Energizes VHF-FM transmitter.
			TLM INPUTS PCM HIGH	No effect on bit rate.
			LOW	Switches from 1.6 KBS to 51.2 KBS.
				NOTE: If data is being recorded, DSE will automatically stop if TAPE RECORD-SPEED switch is not positioned to HIGH.
06	Deactivates system B abort request light	K2 (RESET)		MDC-3
	Activates system B abort request light	K2 (SET)		MDC-3 turns on abort light.

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UHF position, the UHF up-data mode is selected and 28-volt d-c power is applied to the UDL power supply. The S-BAND position also applies 28-volt d-c power, but selects the S-band up-data mode and deactivates the UHF/FM receiver. Another control, located on MDC-19, is the two-position spring-loaded UP TLM CMD switch. When set momentarily to the RESET position, all "reset" commands listed in the UDL real time commands chart are commanded. This nullifies all "set" commands which have been received from the MSFN. An UP TLM - ACCEPT/BLOCK switch (MDC-14) is also provided which enables the crew to permit or prevent G&N up-data from affecting the guidance computer.

## 2.8.3.2.9 Central Timing Equipment (CTE).

The CTE provides precision square wave timing pulses of several frequencies to time-correlate all S/C time-sensitive functions. It also generates and stores the real-time day, hour, minute, and second time-from-launch (TFL) in binary-coded decimal (BCD) format for display and transmission to the MSFN. (See figure 2.8-13.)

In the primary or normal mode of operation, the Apollo guidance computer (AGC) provides a 1024-kc sync pulse to the CTE. This automatically synchronizes the CTE with the AGC and provides a stability of  $\pm 2 \times 10^{-6}$  parts in 14 days. In the event of sync pulse failure, the CTE automatically switches to the secondary mode of operation with no time lapse and operates using its own crystal oscillator at a stability reduced to  $\pm 2.2 \times 10^{-6}$  parts in 5 days.

The CTE contains two power supplies for redundancy. Each one is supplied from a different power source and through separate circuit breakers. These circuit breakers, CENTRAL TIMING SYS - MN A and - MN B on MDC-22, provide the only external means of control for the CTE. The two power supplies provide parallel 6-volt d-c outputs, either one of which is sufficient to power the CTE.

The timing signals generated by the CTE, and their applications, are listed in the CTE Outputs chart.

CTE Outputs		
Signal	Destination	Purpose
512-kc square wave	PCM TLM equipment	Synchronization of internal clock
	PMP equipment	Modulating signal for S-band emergency key transmission
6.4-kc square wave	EPS inverters (three)	Synchronization of 400-cycle a-c power

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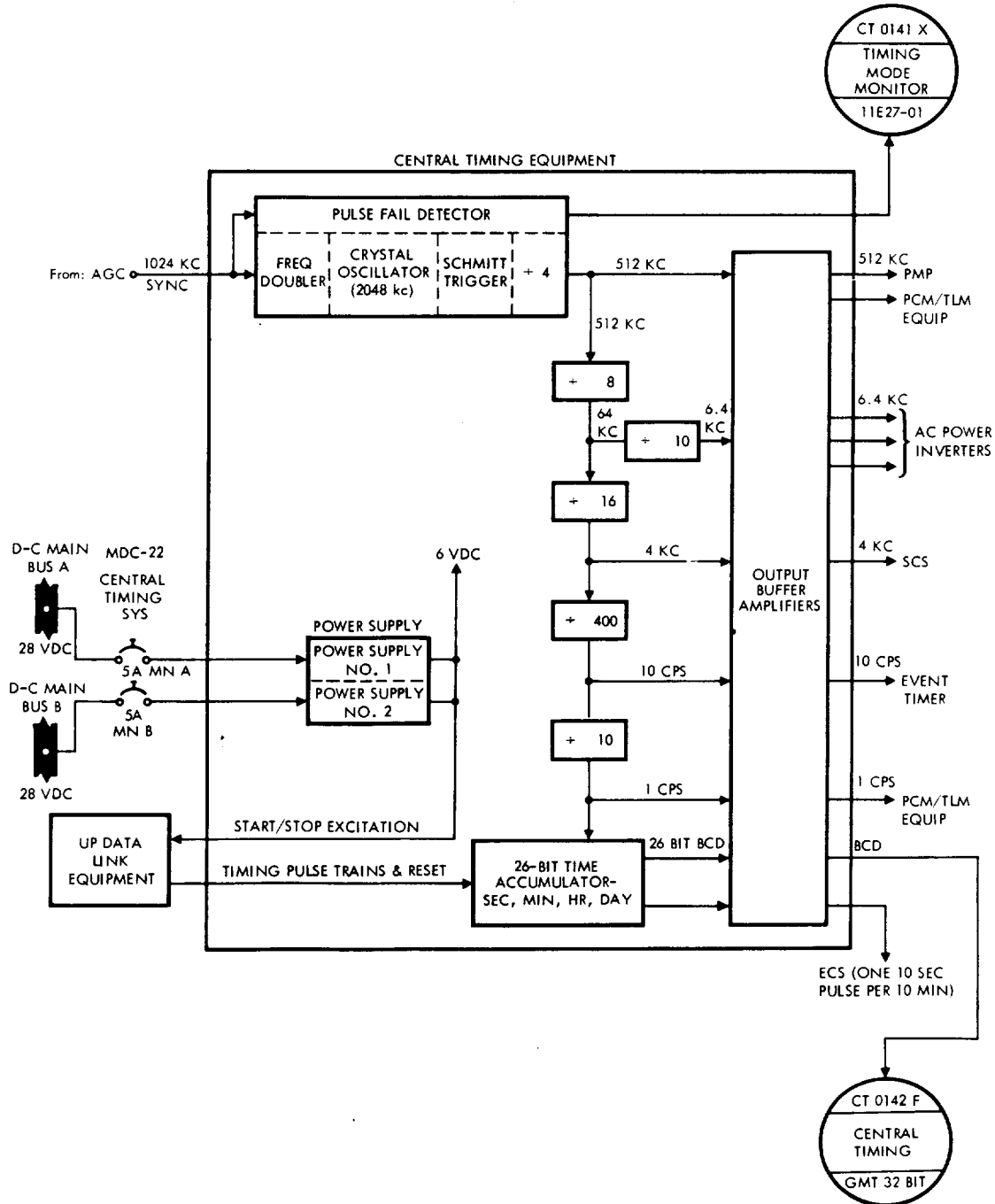


Figure 2.8-13. Central Timing Equipment

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Signal	Destination	Purpose
4-kc square wave	SCS	Synchronization of X-axis accelerometer integrator
10-cps square wave	Displays	Digital event timer
1 cps	PCM TLM equipment	Synchronization of subframe of PCM data, Displays, and T-Timer
DC	PCM TLM equipment	Pulse-fail detection and indication. (Sampling rate equals 10 samples/sec, 5 $\mu$ sec pulse duration.)
Binary coded decimal time code	PCM TLM equipment	Provides time code data to TLM in BCD format (TLM measurement No. CT0142F, C T-GM5 32 bit).
1 pulse per 10 minutes	ECS	Supplies pulse every 10 minutes to ECS circuitry which opens a solenoid for 10 seconds in every 10 minutes to remove water from space suits.

2.8.3.2.10 Voice Recorders

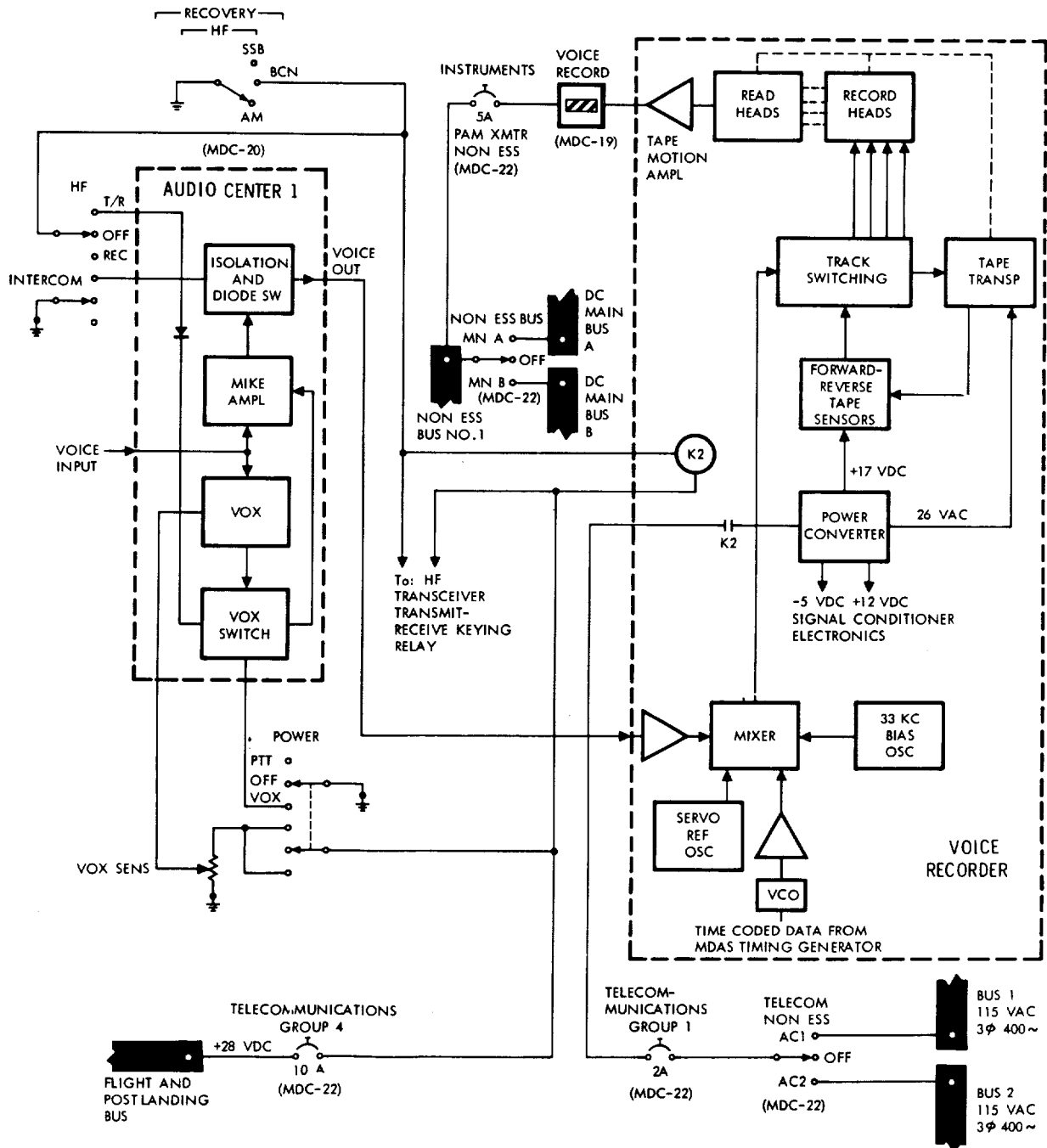
Two voice recorders have been provided to enable the crewmembers to keep a voice log of mission activities. Both units are mounted in the right-hand equipment bay, one in an operating condition and the other stowed. Changeover to the inoperative recorder is made by changing the electrical power connector.

Each tape recorder provides 450 feet of 1/4-inch tape which operates at a speed of 0.6 inches per second. The use of tape reversal, automatic head switching, and four individual recording heads provide ten hours of usable recording time per tape recorder. The information contained on the tape cannot be dumped during flight but must be played back utilizing suitable GSE.

To ready the connected voice recorder for operation, the following switch positions must be selected: the RCDR/HF switch to T/R (MDC-13, -23, -26), the intercom switch to T/R, the HF power switch to OFF (MDC-20), and the mode selector to SSB or AM. (See figure 2.8-14.) Actual activation of the voice recorder is possible three ways: two correct; one wrong. The first correct activation path has the POWER switch at PTT (MDC-13, -23, -26) and the PTT pushbutton on the cobra cable depressed. The other correct method of activation requires the POWER switch to be at VOX and the VOX circuit enabled or the PTT pushbutton

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NOTE: ONLY COMMAND PILOT AUDIO CENTER MODULE AND CONTROLS ARE INDICATED.

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Figure 2.8-14. Voice Tape Recorder

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depressed. The connected voice tape recorder can be inadvertently activated by positioning the HF mode switch to BCN (MDC-20). This would continuously run the connected voice tape recorder until it used up its tape. A VOICE RECORD flag indicator (MDC-19) will display the striped area when recording is in progress. The indicator grey area will be displayed when voice recording is not in progress or the tape supply has been exhausted during recording.

The stowed voice recorder may be placed in operating condition by moving the RCDR/HF switch to OFF (MDC-13, -23, and -26), removing the electrical connector from the exhausted recorder, and installing it to the connector on the stowed recorder. Operation is resumed by moving the RCDR/HF switch to T/R (MDC-13, -23, or -26).

NOTE To include the timing reference while recording on the voice tape recorder, the MDAS MAIN POWER switch must be ON (LEB compartment C) and the TIMER switch must be at "NORMAL."

### 2.8.3.3 RF Electronics Equipment Group.

The RF electronics equipment group includes all T/C equipment which functions as RF transmitters or receivers. The antenna used by this equipment are mentioned only briefly in this paragraph. More information on the antennas can be found in the paragraph on antenna equipment.

### 2.8.3.3.1 VHF/AM Transmitter-Receiver Equipment.

The VHF/AM transmitter-receiver equipment (figure 2.8-15) provides the primary means for in-flight voice communications with the MSFN. It is contained in the same electronics package as the VHF recovery beacon equipment, in the LEB.

Two modes of operation are possible: simplex and duplex. The simplex mode will normally be utilized. The duplex mode will be used on future missions for EVA and LEM communications. During recovery, the transmitter can be utilized as a backup VHF recovery beacon by holding down the PTT key.

The transmitter operates at 296.8 mc in both operational modes. The receiver contains two "front ends." The receive 1 front end operates at 296.8 mc and is used for simplex operations. For duplex operations, the receive 2 front end, which operates at 259.7 mc, is selected.

The VHF/AM transmitter-receiver is controlled by the VHF-AM controls on MDC-20. The T/R/OFF/REC switch activates the transmitter and receiver when in the T/R position; the REC position activates the receiver alone; the OFF position removes power from both. Simplex or duplex operation is selected by placing the RCVR switch to 1 or 2, respectively. The remaining, thumbwheel-type SQUELCH control can be rotated up or down to increase or decrease the sensitivity of the squelch gate.

Audio to and from the VHF-AM is controlled by the VHF-AM-T/R/OFF/REC switch on MDC-13, -23, -26. Voice transmission is possible when this switch is at T/R, the POWER switch is at PTT, the cobra cable PTT/CW switch is at PTT and the PTT key is pressed.

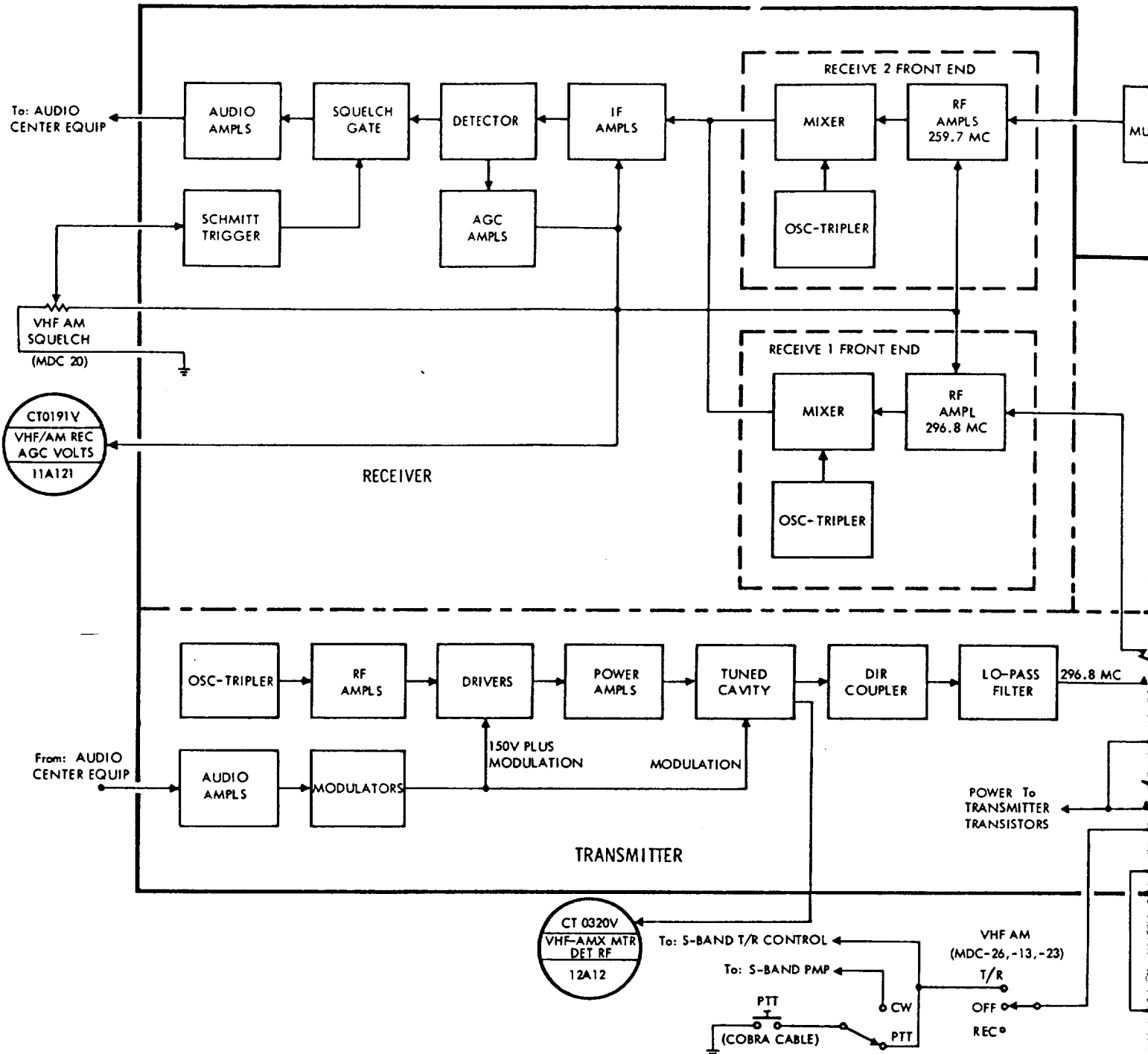
NOTE The POWER switch can also be at VOX, but actual keying of the VHF/AM must be via the PTT circuit.

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## VHF/AM TRANSMITTER-RECEIVER

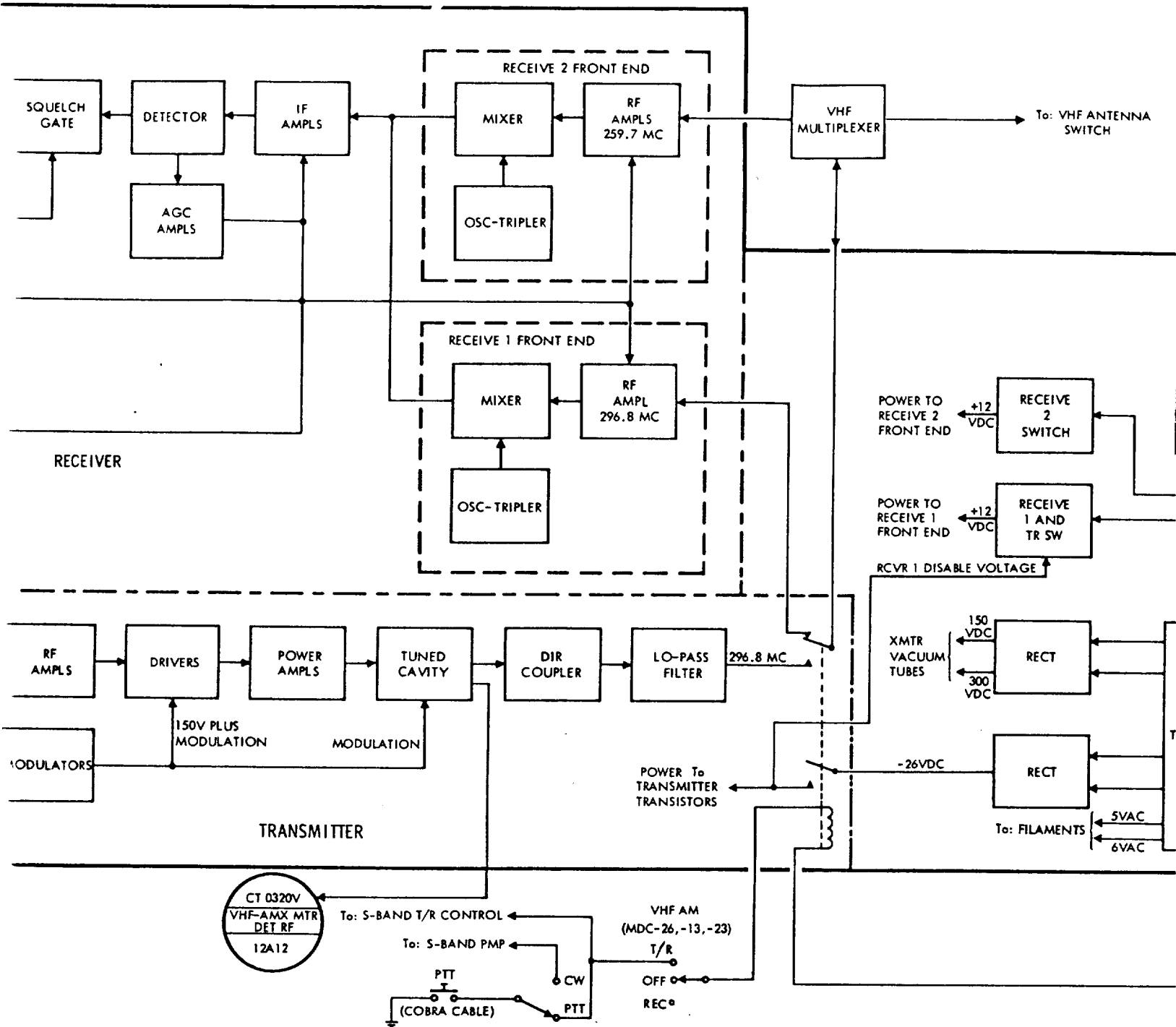


FOLDOUT FRAME /

12/1/20

12/1/20

## VHF/AM TRANSMITTER-RECEIVER



Figure

Mission \_\_\_\_\_ Basic

BOLDOUT FRAME 2



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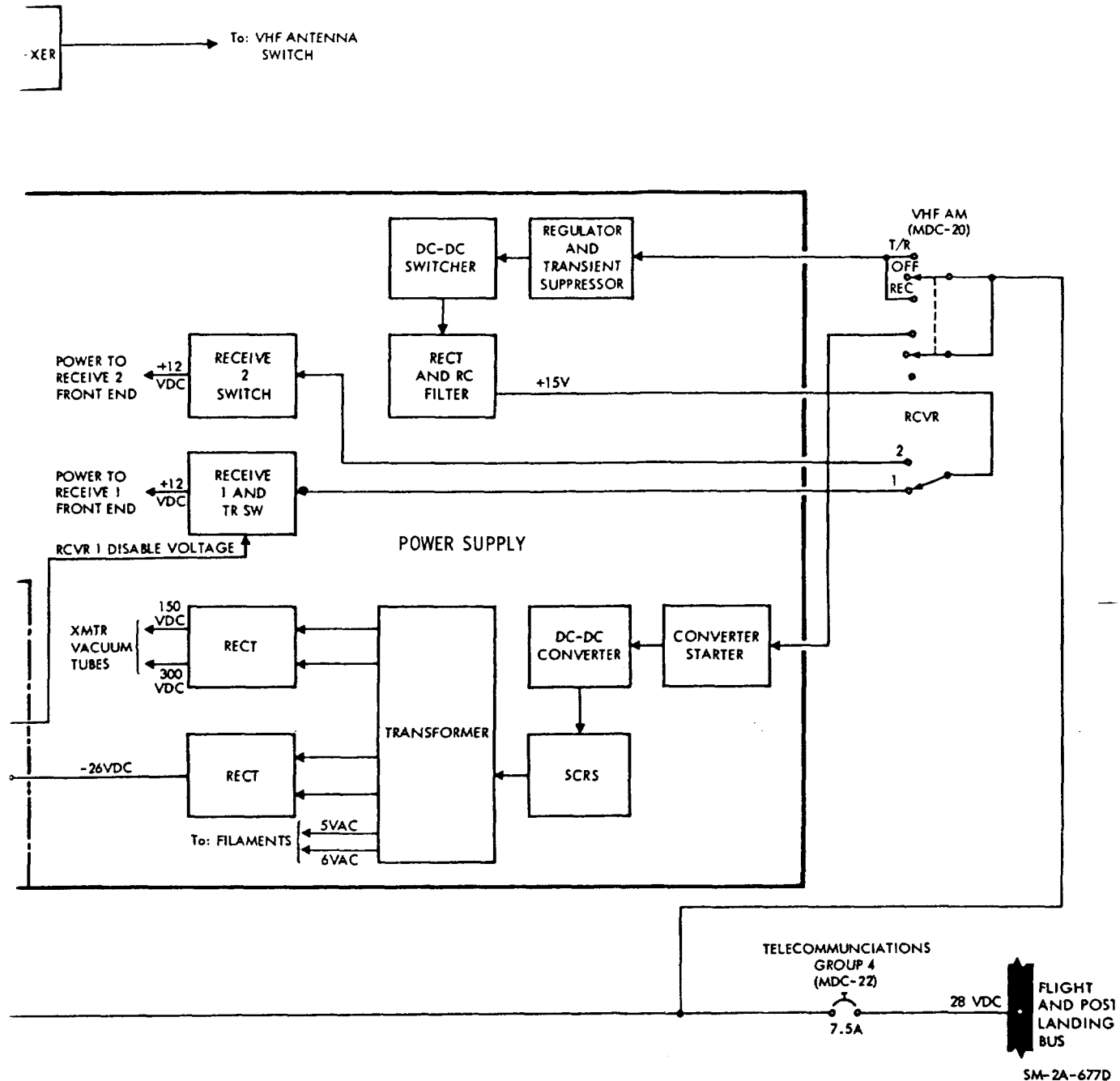


Figure 2.8-15. VHF/AM Transmitter-Receiver Equipment

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The VHF portion of the upper or lower SCIN antenna is used during flight. VHF recovery antenna No. 2 is used during recovery. Antenna selection is made with the VHF ANTENNA switch on MDC-20.

2.8.3.3.2 HF Transceiver Equipment.

The HF transceiver equipment (figure 2.8-16) is the primary means to aid recovery operations during the postlanding phase of the mission by providing long-range, simplex, voice communications and beyond line-of-sight direction finding capabilities. It is contained in the same electronics package as the VHF-FM transmitter equipment in the LEB.

The HF transceiver equipment is controlled by the RECOVERY-HF switches on MDC-20. The ON/OFF switch, when placed to ON, connects d-c power to the transceiver. The SSB/BCN/AM switch is used to select the operational mode. Three modes of operation are available; single side-band (SSB), beacon (BCN), and amplitude modulation (AM). The BCN mode is used to transmit an unmodulated, continuous wave, direction finding beacon. The SSB and AM modes are used for long-range, simplex, voice communications. The operating frequency is 10.006 mc for the transmitter and receiver in all modes.

The audio center equipment supplies the audio input to the modulator in the translator module and accepts the detected audio signal from the receiver module of the transceiver. The HF transmitter is keyed by VOX or PTT.

The HF recovery antenna is used for transmission and reception and will be deployed after touchdown as part of the postlanding sequence of operations. The transceiver must not be operated prior to antenna deployment or damage may occur.

2.8.3.3.3 VHF/FM Transmitter Equipment.

The sole function of the VHF/FM transmitter equipment (figure 2.8-17) is to transmit PCM TLM data to the MSFN. These data are supplied to the VHF/FM transmitter by the PMP in the form of a 3-volt p-p pulsating d-c, modulating signal at a rate of 51,200 bits per second (bps) or 1600 bps. The bit rate depends on the PCM rate selected.

The nominal (center) frequency of the emitted RF carrier is 237.8 mc. Because the transmitter is frequency modulated, the 3-volt p-p modulating signal causes a frequency deviation of  $\pm 125$  kc. The resulting 10-watt RF output is fed to the VHF portion of the VHF/2-KMC SCIN antennas.

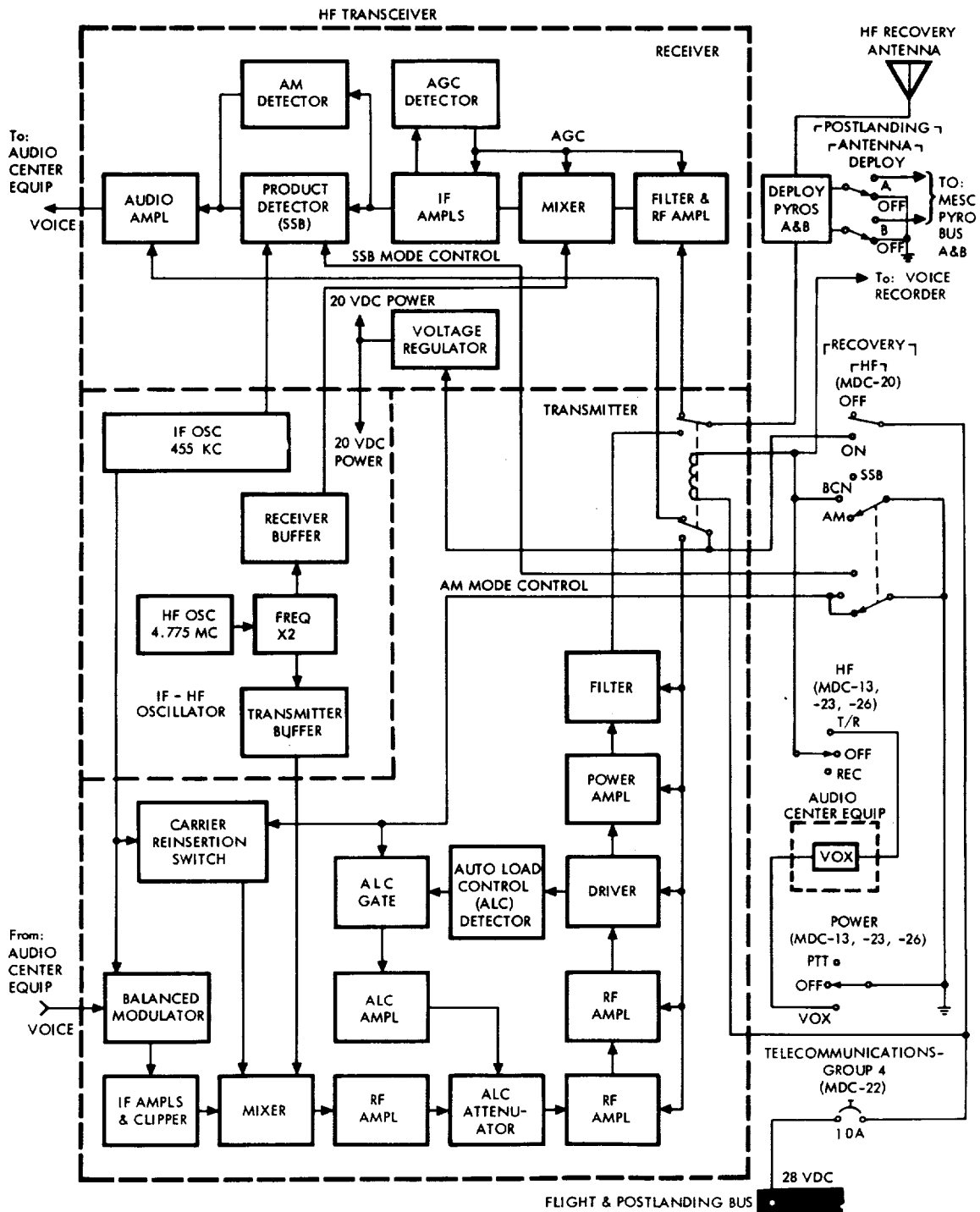
The only external control for the VHF/FM transmitter equipment is the VHF-FM — ON/OFF switch on MDC-20 which energizes a relay in the transmitter, applying a-c power to the equipment. If the switch is set to OFF, the VHF/FM transmitter can be activated from the MSFN by a real-time command via the UDL equipment,

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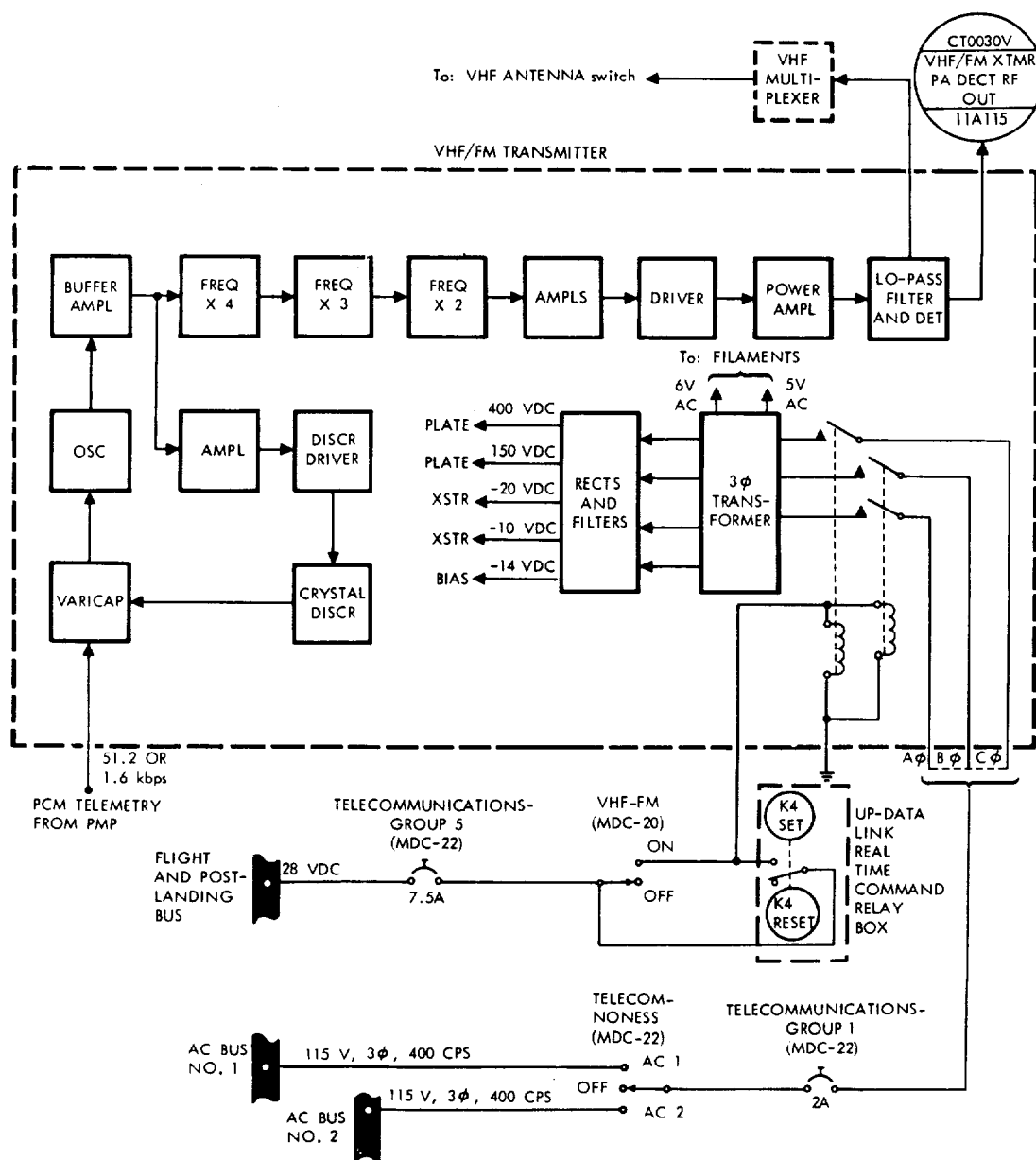
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Figure 2.8-16. HF Transceiver Equipment

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T/C

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Figure 2.8-17. VHF/FM Transmitter Equipment

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2.8.3.3.4 Unified S-Band Equipment (USB E).

The USB E (figure 2.8-18) consists of a receiver, transmitter, and power supply contained in a single electronics package in the lower equipment bay. Although primarily designed for deep-space communications, the USB E will be tested on this mission and used as backup for in-flight voice communications, tracking and ranging, transmission of PCM data, and reception of up-data. The USB E also provides the sole means for transmission of TV

The USB E tracking method employed is the two-way or double-doppler method. In this technique, a stable carrier of known frequency is transmitted to the S/C where it is received by the phase-locked receiver, multiplied by a known ratio, and then retransmitted to the MSFN for comparison. Because of this capability, the USB E is also referred to as the S-band transponder. From the double-doppler tracking method, S/C velocity, acceleration, and range can be determined.

For determining S/C range, the MSFN phase-modulates the transmitted carrier with a pseudo-random noise (PRN) binary ranging code. This code is detected by the S/C USB E receiver and used to phase-modulate the carrier transmitted to the MSFN. The MSFN receives the carrier and measures the amount of time delay between transmission of the code and reception of the same code, thereby obtaining an accurate measurement of range. Once established, this range can be continually up-dated by the double-doppler measurements discussed earlier. The MSFN can also transmit up-data commands and voice signals to the S/C USB E by means of two subcarriers: 70 kc for up-data and 30 kc for up-voice.

The USB E receiver is a phase-tracking receiver that accepts a 2106.4-mc, phase-modulated RF signal containing the up-data and up-voice subcarriers and a pseudo-random noise (PRN) code when ranging is desired. This signal is supplied to the receiver via the diplexer in the S-band power amplifier equipment and presented to two separate detectors: the loop phase detector and the ranging phase detector. In the ranging phase detector, the 9.531-mc IF is detected; and the 70-kc up-data and 30-kc up-voice subcarriers are extracted, amplified, and routed to the up-data and up-voice discriminators in the PMP equipment. Also, when operating in a ranging mode, the PRN ranging signal is derived, filtered, and routed to the USB E transmitter as a modulating signal input to the phase modulator. In the loop phase detector, the 9.531-mc IF signal is detected by comparing it with the loop reference frequency. The resulting d-c output is used to control the frequency of the 19.0625-mc voltage-controlled oscillator (VCO). The output of the VCO is used as the reference frequency for receiver circuits as well as for the transmitter. The receiver is also provided with automatic gain control (AGC) and antenna selector circuitry which automatically selects the proper SCIN antenna when the S-BAND ANTENNA switch is in the AUTO position. The AGC circuitry also supplies a signal to the S-BAND ANT S-meter located on MDC-19. By observing this meter and rotating the S/C, the optimum S/C attitude for S-band communications can be attained.

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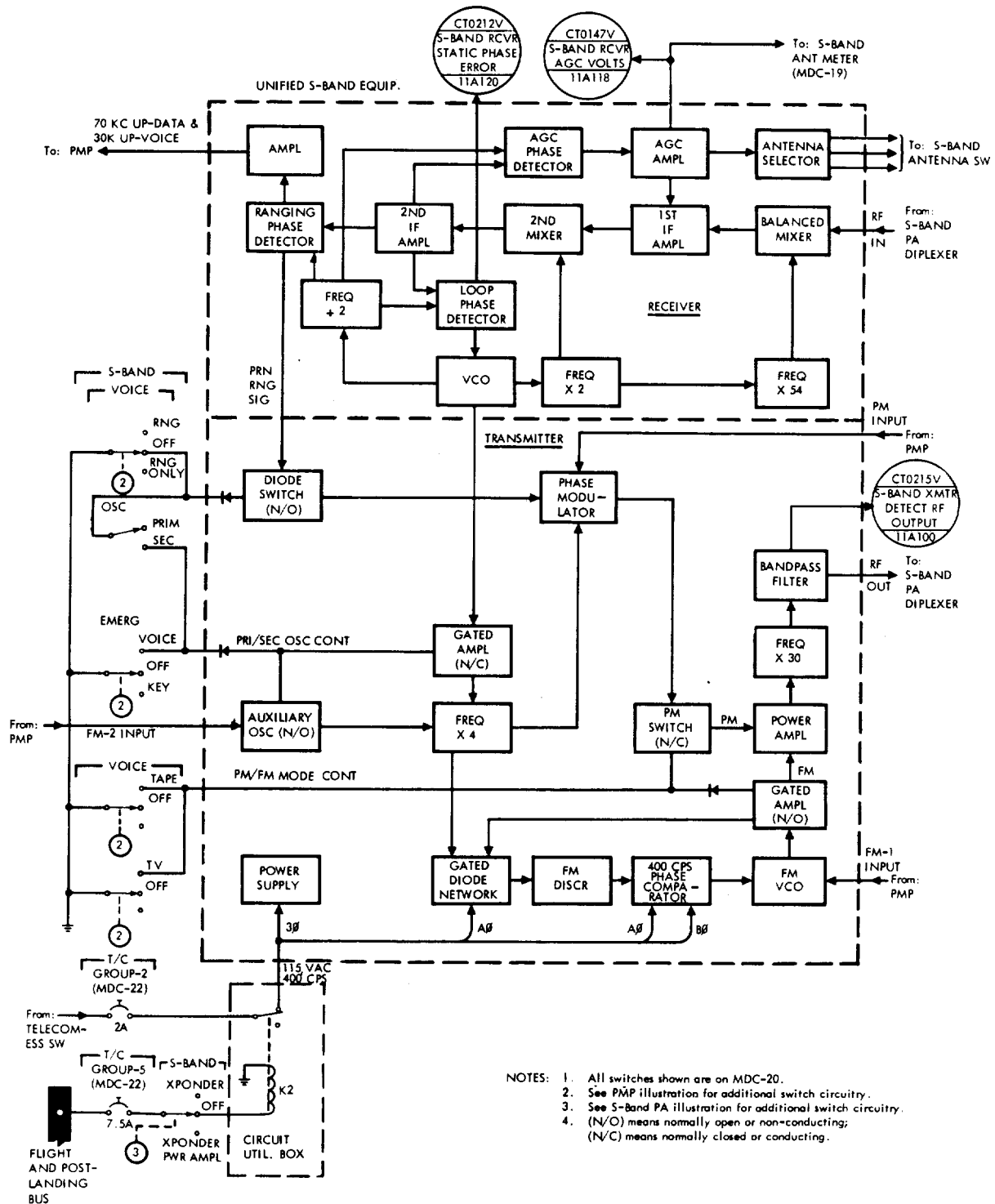


Figure 2.8-18. Unified S-Band Equipment

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The USBE transmitter is capable of transmitting a 2287.5-mc signal, either phase-modulated or frequency-modulated. In the PM mode, the initial transmitter frequency is obtained from one of two sources: the VCO in the phase-locked USBE receiver or the auxiliary oscillator in the transmitter. When operating in the FM mode, the VCO or auxiliary oscillator initial frequency is not multiplied and used directly, but is used to control the frequency of a third oscillator, the FM VCO. The FM VCO is the source for the frequency-modulated 2287.5-mc signal.

Output mode and frequency source are controlled by the S-BAND group of switches on MDC-20. The VOICE and EMERG switches, contained in this group, also have an effect on PMP operation, thus ensuring compatibility between USBE and PMP modes. All data to be transmitted by the USBE is supplied by the PMP. Normally, the initial transmitter frequency is obtained from the receiver VCO. In case of failure of the VCO or S-band PA equipment, the auxiliary oscillator can be selected. This is done by moving the OSC switch from PRIM to SEC (with the RNG/RNG ONLY switch at the normal, center position) or by placing the EMERG switch to VOICE. If the latter is done, the PMP will provide a voice modulating signal directly to the auxiliary oscillator.

With all three S-BAND - VOICE switches and the S-BAND - EMERG switch set at their center positions, the USBE transmits a phase-modulated signal containing PCM TLM and voice data from the PMP. Setting the RNG/RNG ONLY switch to RNG, enables the PRN ranging code to be transmitted also. Setting this switch to RNG ONLY, adds the PRN ranging code but eliminates the PCM TLM portion of the PM input from the PMP. This mode is used to increase the strength of the PRN ranging code received by the MSFN. The other two S-BAND - VOICE switches are the TAPE and the TV switches. For PM operation, both of these switches must be at their center, off position. Setting either of them to any other position changes the USBE mode to FM for increased band-width and selects the FM-1 output of the PMP. Thus, these four switches (the three VOICE switches and the EMERG switch) are used to establish the operational mode. Only one switch at a time may be placed to any position other than center for proper operation of the USBE and PMP. For further description of PMP outputs, refer to the discussion of the PMP equipment.

The USBE is activated by the S-BAND - XPONDER/XPONDER PWR AMPL switch. Setting this switch to XPONDER or XPONDER PWR AMPL energizes a relay that applies 115 volts ac to the USBE power supply, which provides +15 volts dc and -15 volts dc outputs to the USBE transmitter and receiver. The RF output of the USBE transmitter is fed to the S-band power amplifier equipment. Here, the signal is either bypassed directly to the S-BAND ANTENNA switch or amplified and then fed to the S-BAND ANTENNA switch.

#### 2.8.3.3.5 S-Band Power Amplifier Equipment.

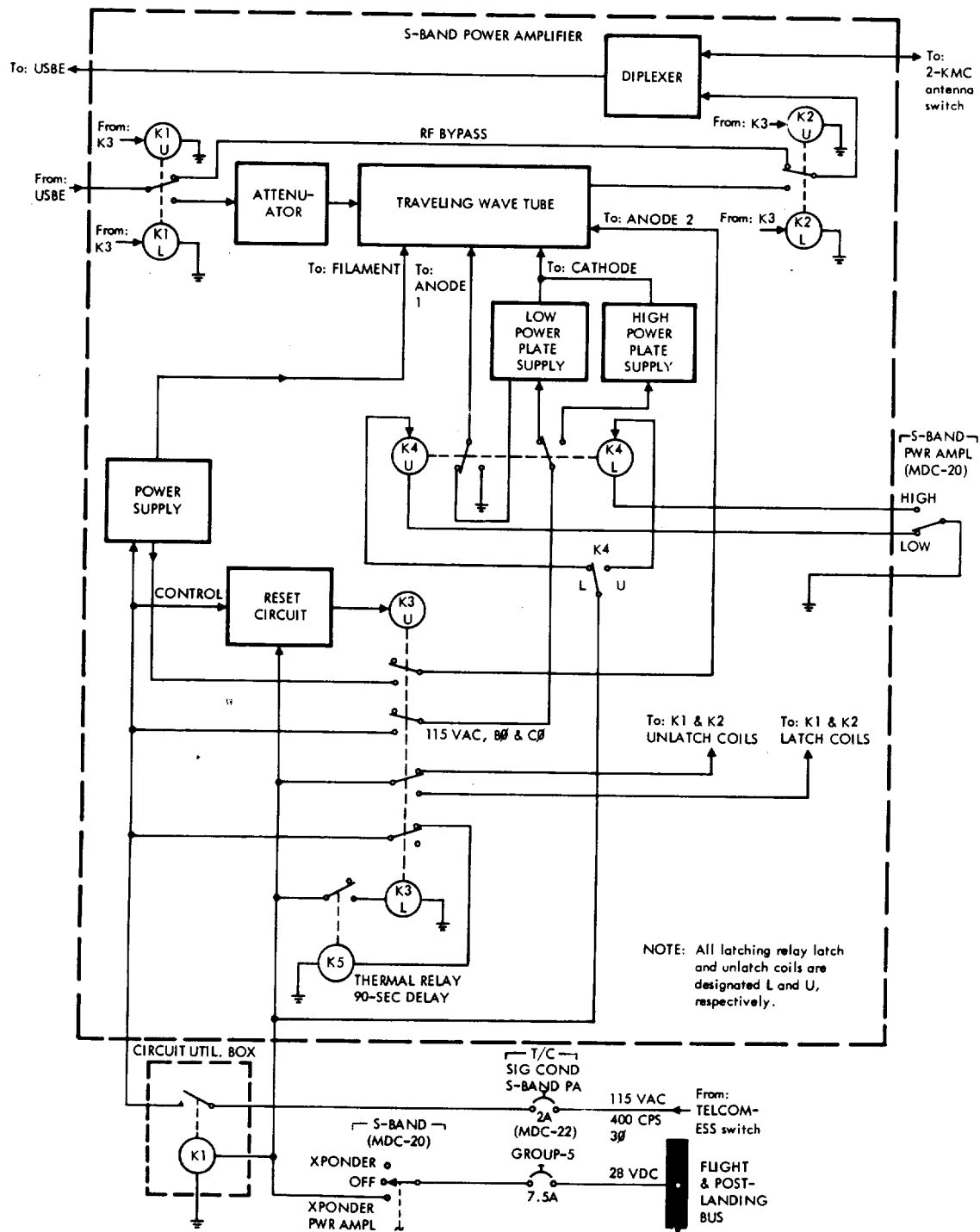
The S-band power amplifier (PA) equipment (figure 2.8-19) is used to amplify the RF output from the USBE transmitter when additional signal

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Figure 2.8-19. S-Band Power Amplifier Equipment

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strength is required for adequate reception of the S-band signal by the MSFN. It consists of a diplexer, a traveling-wave tube for amplification, power supplies, and the necessary switching relays and control circuitry. The S-band PA is contained in a single electronics package located in the lower equipment bay.

All received and transmitted S-band signals pass through the S-band PA diplexer. The 2106.4-mc S-band carrier received by the S/C enters the S-band PA diplexer from the S-band antenna equipment. The diplexer passes the signal straight through to the USBE receiver. The 2287.5-mc output signal from the USBE transmitter enters the S-band PA where it is either bypassed directly to the diplexer and out to the S-band antenna equipment, or amplified first and then fed to the diplexer. There are three power amplifier modes of operation: bypass, low power, and high power.

Two of the S-BAND switches on MDC-20 are used to control the S-band power amplifier. Setting the XPONDER/XPONDER PWR AMPL switch to the XPONDER PWR AMPL position energizes the USBE power supply and applies 3-phase 115-volt a-c power to the S-band PA through relay K1 in the circuit utilization box. This also activates the 90-second time-delay relay in the S-band PA. Upon initial application of power, only the low-voltage power supply is energized, which applies power to the traveling wave tube heater. After 90 seconds, the RF signal from the USBE transmitter is switched from the bypass circuit to the amplifier circuit and 3-phase 115-volt a-c power is applied to either the low power or high power section of the high-voltage power supply, which supplies the correct operating voltages to the remaining elements of the traveling-wave tube. Selection of the low power (LOW) or high power (HIGH) mode is controlled by the S-BAND - PWR AMPL - HIGH/LOW switch.

2.8.3.3.6 C-Band Transponder Equipment

An earth-based C-band tracking and ranging system is used to provide S/C position data to the MSFN during the launch, near-earth, and entry phases of the mission. The function of the S/C C-band transponder equipment (figure 2.8-20) is to effectively extend the range of the system beyond that which would be possible using skin-tracking techniques only. Upon reception of a properly coded pulsed interrogation from the earth-based equipment at 5690 mc, the C-band transponder transmits a response pulse to the earth after a 3-microsecond delay at 5765 mc.

The C-band transponder contains four receivers, a transmitter, a power supply, and associated circuitry for comparing and decoding received signals and switching antennas. There are four C-band antennas, one for each receiver, located around the perimeter of the command module. The interrogation may be received by any one or more of the four antennas and routed through circulators to the associated receivers. If the pulses are properly coded the comparator determines which antenna received the strongest signal and activates the switch driver, which drives the RF

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Switch Name Function	S-Band Power XPONDER- OFF- XPONDER PWR AMPL	Pwr Ampl HIGH LOW	OSC PRIM or SEC	Ranging RNG- Off- RNG ONLY	Tape	TV	Emergency UP Data S-Band Ant			Remarks
							Voice- Off- Key	S-Band- Off- UHF	AUTO- UPPER- LOWER	
S-band PM mode real time voice, telemetering and ranging	XPONDER PWR AMPL	LOW	PRIM	RNG	Off	Off	Off	As reqd	UPPER or LOWER as reqd	
S-band PM mode real time voice and data	XPONDER PWR AMPL	LOW	PRIM or SEC	Off	Off	Off	Off	As reqd	UPPER or LOWER as reqd	
S-band FM mode real time voice, data and TV	XPONDER PWR AMPL	LOW or HIGH	PRIM or SEC	Off	Off	TV	Off	As reqd	UPPER or LOWER as reqd	TV camera power switch must be on.
S-band FM mode real time voice, play back data	XPONDER PWR AMPL	LOW	PRIM or SEC	Off	TAPE	Off	Off	As reqd	UPPER or LOWER	DSE switches must be properly configured for play back.
S-band emergency voice	XPONDER PWR AMPL	LOW or HIGH	PRIM or SEC	Off	Off	Off	VOICE	As reqd	UPPER or LOWER	
S-band emergency key	XPONDER PWR AMPL	LOW or HIGH	PRIM or SEC	Off	Off	Off	KEY	As reqd	UPPER or LOWER	Cobra cable mode switch at CW and PTT button used as key.
S-band reception of up-data	XPONDER or XPONDER PWR AMPL	LOW or HIGH	PRIM or SEC	RNG Off or RNG ONLY	Off	Off	Off	S-band	UPPER or LOWER	

Notes: 1. TAPE and TV switches are 3-position switches with the down position no longer performing a valid function. The down position of these switches should not be selected.  
2. The TAPE and TV switches should never be in the UP position together.

T.C

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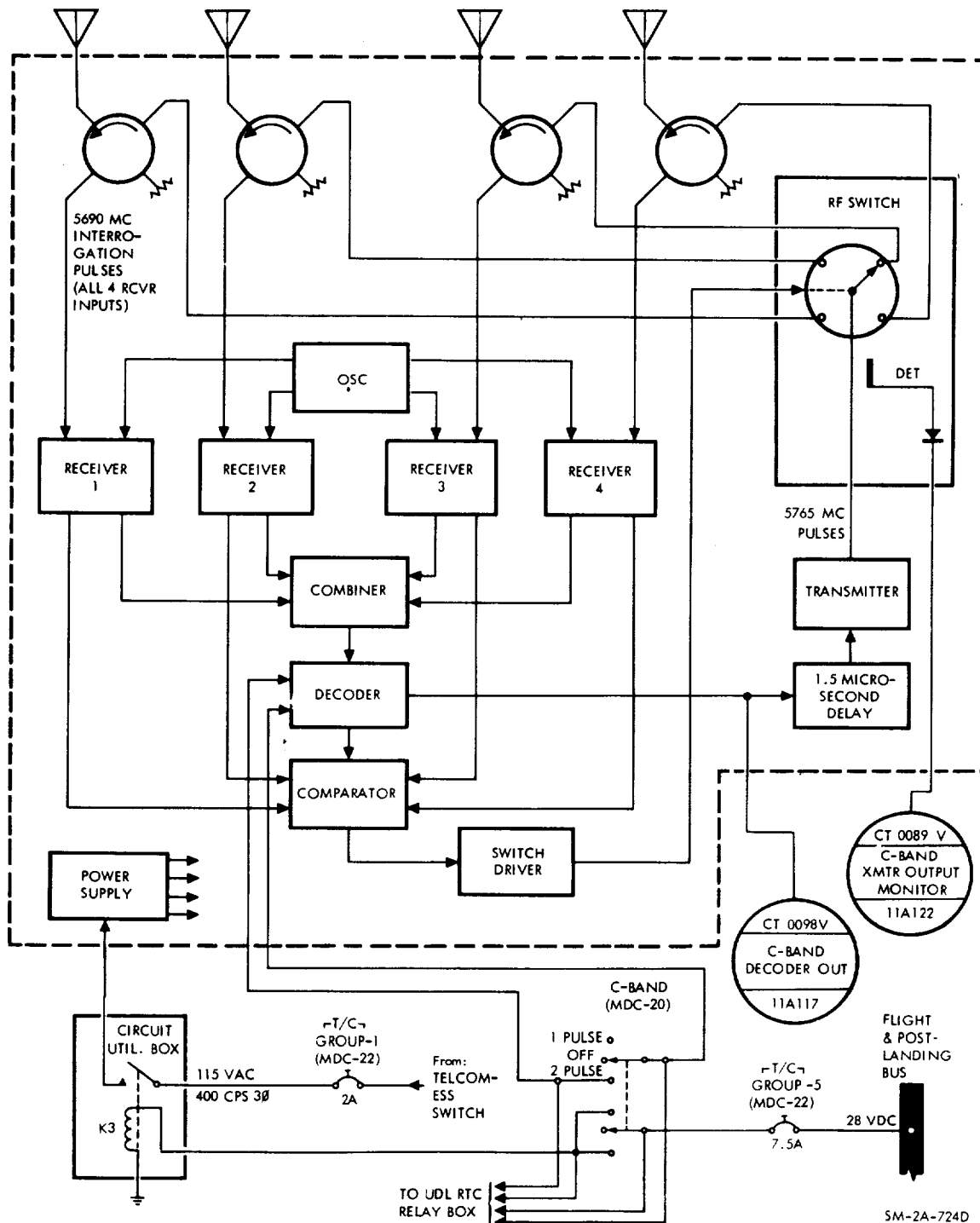


Figure 2.8-20. C-Band Transponder Equipment

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switch to the proper antenna position. Three microseconds after interrogation, the transmitter sends a response pulse to the selected antenna. This 3-microsecond delay gives the RF switch time to operate. It also enables MSFN personnel to simultaneously observe the transponder reply and the skin track reply on the same visual display device (cathode ray tube) for comparison.

Two modes of operation can be selected: 1 pulse or 2 pulse. Mode selection will depend on the type of earth-based radar equipment that is being used at a particular area in the orbital path. During the launch and ascent phases of the mission, the 2-pulse mode will be used.

The only external control for the C-band transponder equipment is the C-BAND three-position toggle switch on MDC-20. The OFF position removes a-c power from the equipment; the 1 PULSE and 2 PULSE positions apply a-c power to the equipment and select the mode of operation. Activation and mode selection can also be commanded from the MSFN by a real-time command via the UDL equipment.

2.8.3.3.7 VHF Recovery Beacon Equipment.

The VHF recovery beacon equipment (figure 2.8-21) provides a line-of-sight direction finding capabilities to aid in locating the S/C during the recovery phase of the mission. It is located in the same electronics package as the VHF/AM transmitter-receiver equipment in the LEB. The beacon signal emitted is an interrupted 243-mc carrier, modulated by a 1000-cps square wave. The signal is transmitted for 2 seconds, then interrupted for 3 seconds.

Manual control of the equipment is provided by the RECOVERY — VHF-BCN, two-position ON/OFF switch on MDC-20.

The output of the VHF recovery beacon equipment is fed to VHF recovery antenna No. 1, which is deployed automatically when the main chutes are deployed.

2.8.3.3.8 GFE VHF Survival Beacon/Transceiver.

The VHF beacon/transceiver is a hand-held GFE item to be used in the recovery phase of the Apollo mission. The unit, plus an extra battery, is stored with the survival equipment.

Figure 2.8-22 shows the three major parts of the unit, the transmitter-receiver assembly, the battery pack assembly, and the quarter wave antenna.

The receiver-transmitter assembly and battery pack assembly mate to form a water-tight unit measuring 8 by 4-1/2 by 3 inches. The antenna is an 11-1/2-inch-long tapered flexible steel tape, terminated in a coaxial RF connector, and is normally stored in a retaining spool and clip on top of the radio unit.

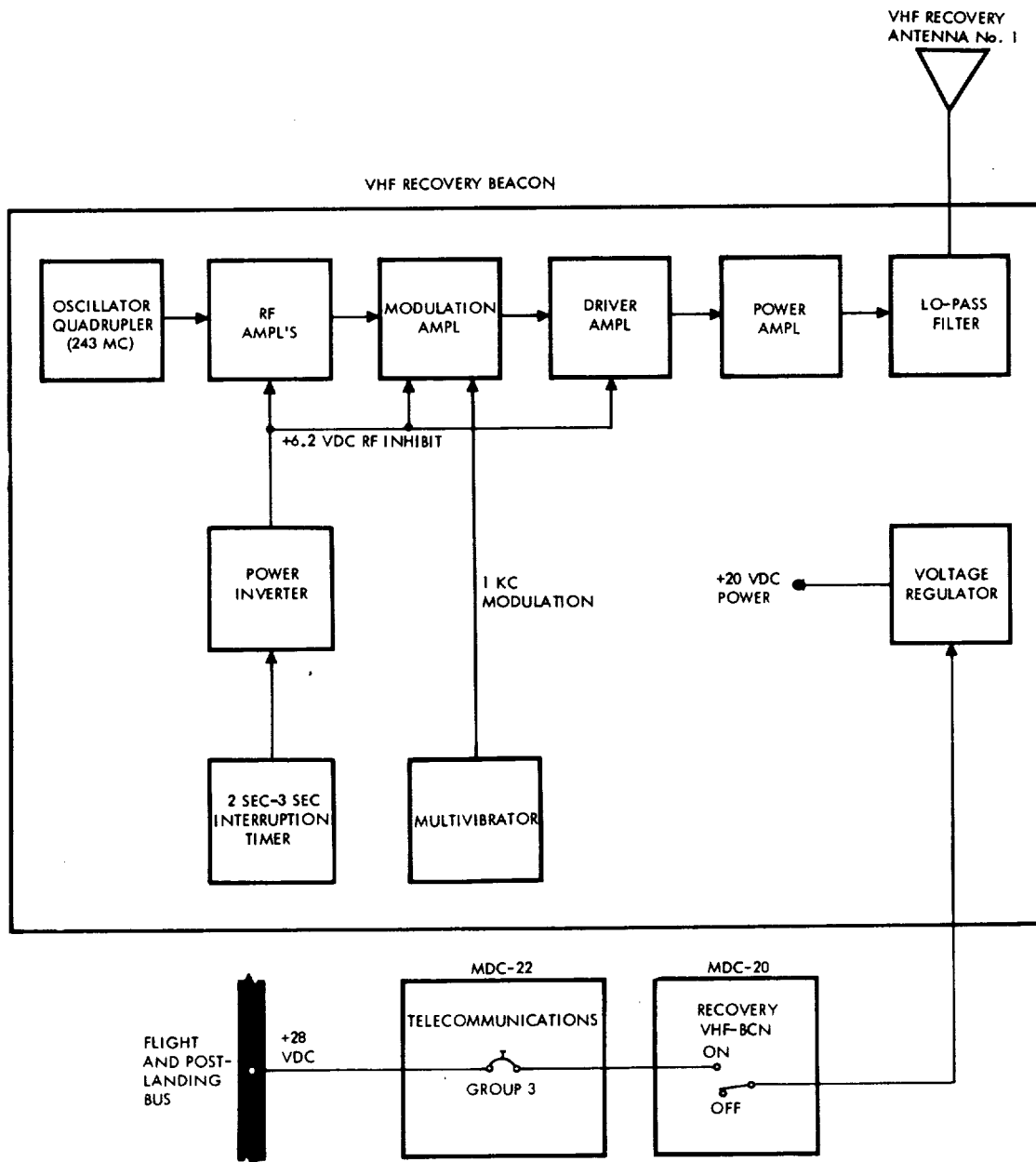
The radio is capable of line-of-sight operation in either of two modes (beacon or voice) through use of either its own antenna or a suitable connected remote antenna. The transmitter output is protected against damage while operating due to accidental shorting of the antenna or submergence of the unit in salt water. In the beacon mode, the transmitter operates unattended, for periods up to 24 hours, to transmit an interrupted 1000-cps tone, amplitude modulated 25 percent on the 243-mc RF carrier. In the

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Figure 2.8-21. VHF Recovery Beacon Equipment

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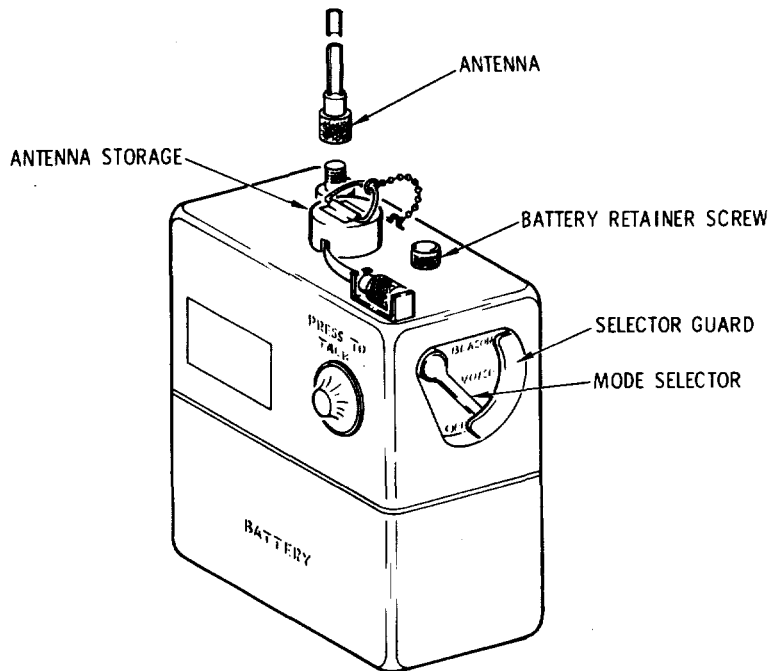


Figure 2.8-22. Survival Beacon/Transceiver Radio

voice mode, the radio provides two-way AM voice communication through use of an integral speaker-microphone and PUSH-TO-TALK switch.

2.8.3.4 Antenna Equipment Group.

The antenna equipment group contains all of the S/C antennas and ancillary equipment used in the T/C system. (See figures 2.8-23 and 2.8-24.)

2.8.3.4.1 VHF/2-KMC Omni-Antenna Equipment.

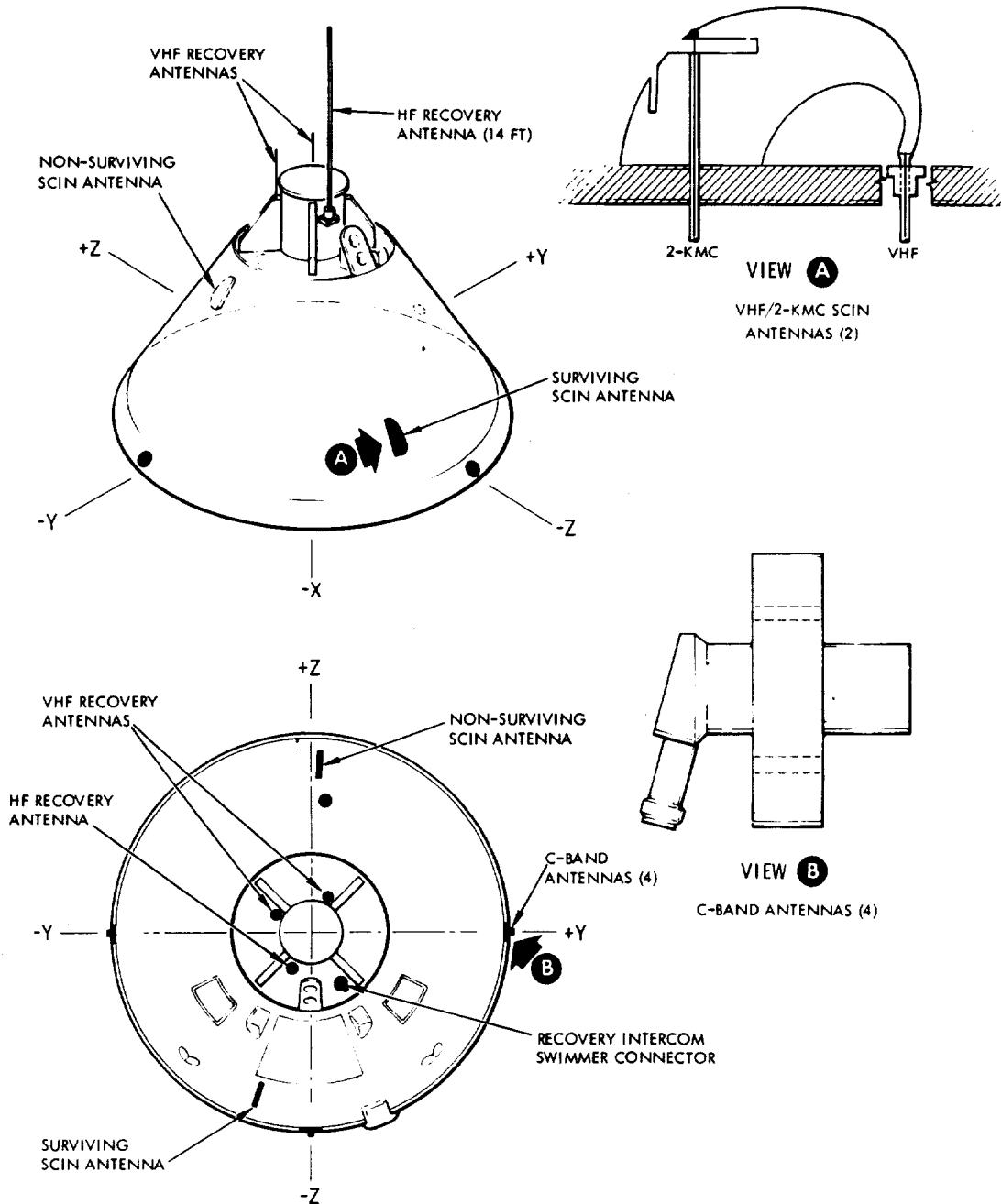
The VHF/2-kmc omni-antennas and corresponding ancillary equipment consists of two VHF/2-kmc SCIN antennas, a VHF multiplexer, a VHF antenna switch, a 2-kmc antenna switch, and the necessary signal and control circuits. The function of this equipment is to provide capabilities for radiation and pickup of RF signals in the VHF and S-band spectrums. The VHF portion of this equipment is used in conjunction with the up-data link (UDL) receiver, the VHF/FM transmitter, and the VHF/AM transmitter-receiver on two frequencies. The 2-kmc portion of this equipment is used with the USBE.

The VHF multiplexer is a passive, six-channel, filtering device which enables six items of VHF transmitting or receiving equipment to utilize one VHF antenna simultaneously. The six channel filters are composed of two or three tuned cavities, each of which function as bandpass filters. No power is required by the device and there are no external controls.

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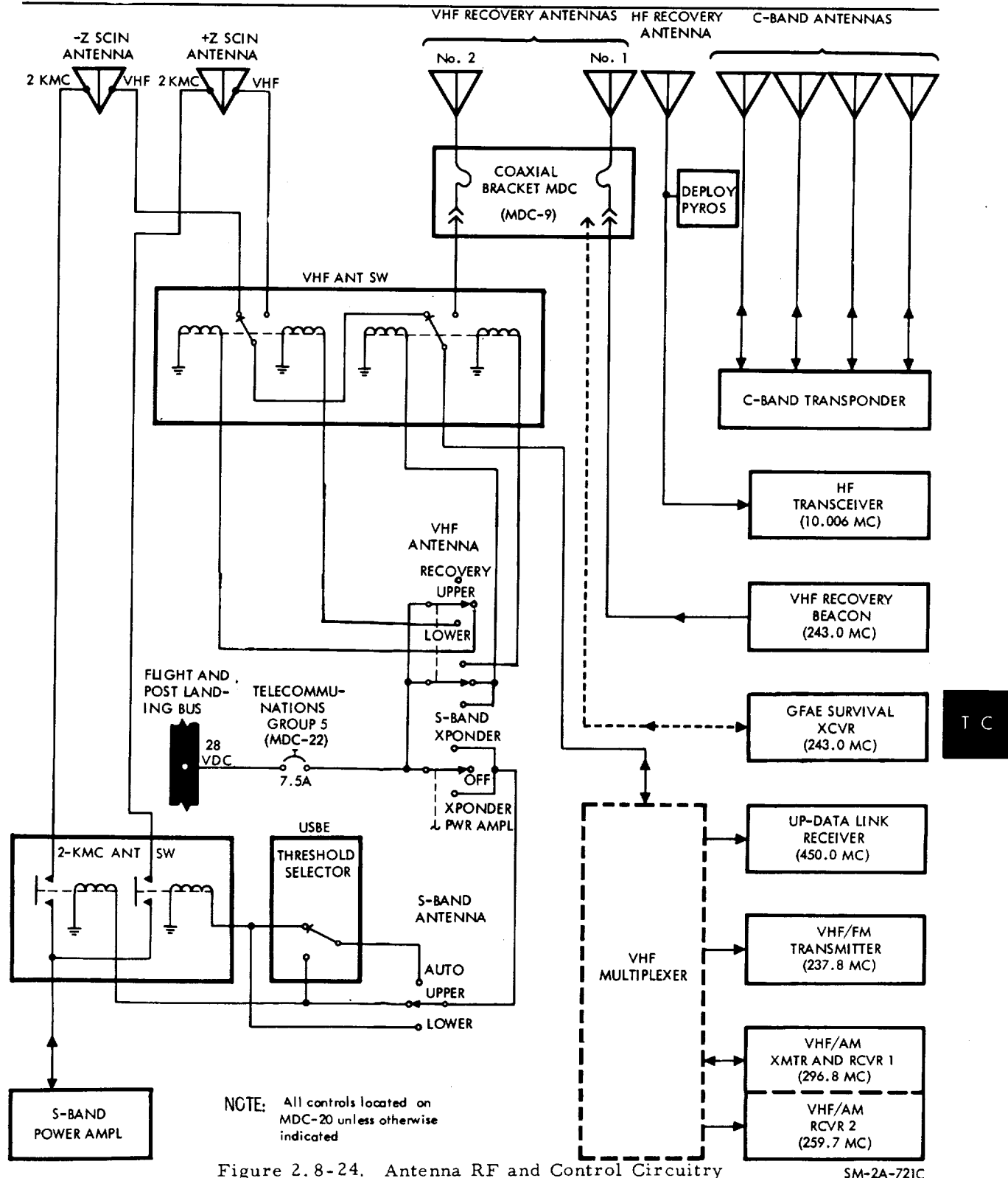
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Figure 2.8-23. Antenna Locations

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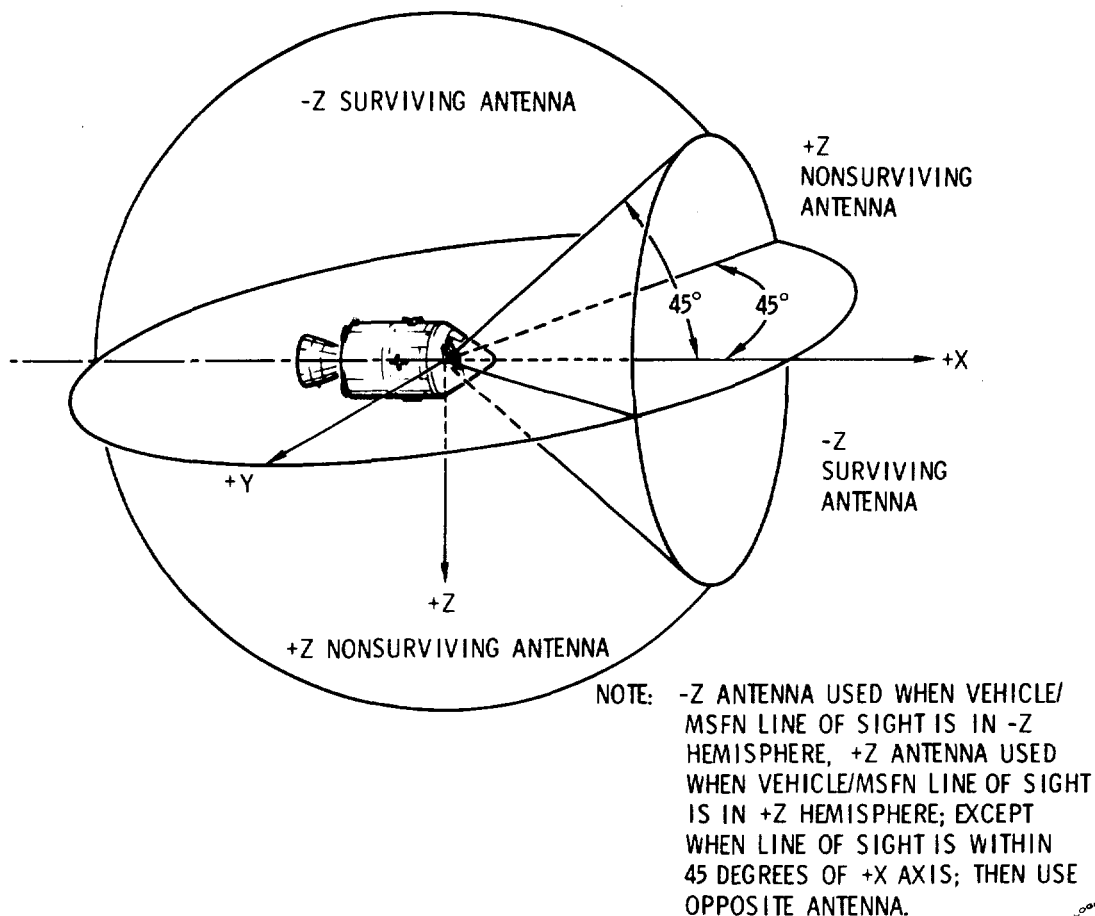


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The VHF/2-kmc SCIN antennas are dual-purpose antennas with approximately hemispherical radiation patterns. Figures 2.8-25 and 2.8-26 show the propagation patterns of the VHF-UHF and S-band portions of the antenna, respectively. The word "SCIN" is an acronym for "SCimitar" and "Notch." Because of its characteristic shape, that portion of the antenna used for VHF is called a scimitar. In the broad end of the scimitar is a notch which functions independently and is used for S-band frequencies.

There are two VHF/2-kmc SCIN antennas; they are located on opposite sides of the S/C. One is located near the +Z axis and is called the +Z or lower SCIN antenna; the other is located near the -Z axis and is called the -Z or upper SCIN antenna. Because of their approximate hemispherical radiation patterns, fully omnidirectional capabilities can be obtained only by switching from one antenna to the other. This is accomplished with the VHF ANTENNA remote control switch on MDC-20 for VHF communications, or with the S-BAND ANTENNA remote control switch, also on MDC-20, for S-band communications.



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Figure 2.8-25. Antenna Switching Regions, VHF-UHF

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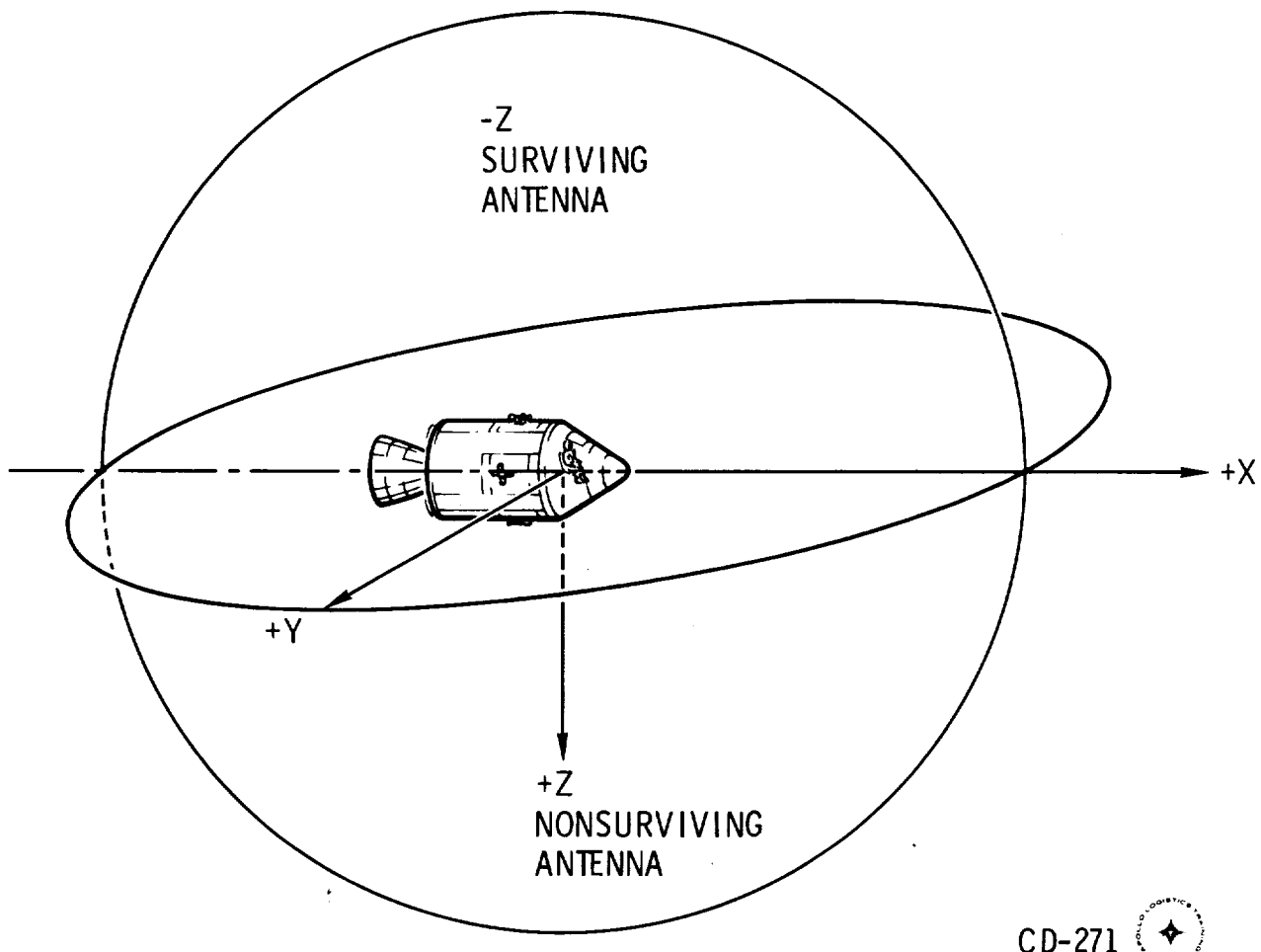


Figure 2.8-26. Antenna Switching Regions, S-Band

The lower (+Z) SCIN antenna may be burned off during entry. The upper (-Z) SCIN antenna is located at a minimum heat point and is covered with ablative material to provide thermal protection for entry survival.

2.8.3.4.2 HF Recovery Antenna Equipment

The HF recovery antenna is provided solely for use with the HF transceiver to provide for voice communication with recovery forces after touchdown. It is stowed inside a canister, located in the forward compartment of the S/C, until deployed by manual activation of a pyrotechnic device. The pyrotechnic device is activated by setting the POST LANDING — ANTENNA DEPLOY switches to their upper positions (A and B), while the MASTER EVENT SEQ CONT switches (2) are at PYRO ARM (MDC-24) position.

2.8.3.4.3 VHF Recovery Antenna Equipment.

There are two VHF recovery antennas, No. 1 and No. 2, stowed in the forward compartment of the S/C. Each antenna consists of a quarterwave

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stub, 11 inches long, and a ground plane. They are automatically deployed 8 seconds after main parachute deployment during the descent phase of the mission.

VHF recovery antenna No. 1 is connected to the VHF recover beacon equipment through a coaxial connector on the coaxial bracket, MDC-9. VHF recovery antenna No. 2 is to be used with the VHF/AM transmitter-receiver equipment, thus it is connected to the VHF antenna switch, also through a connector on the coaxial bracket. The purpose of the coaxial bracket is to allow either of the VHF recovery antennas to be used with the GFAE survival transceiver. This requires that the coaxial cable from one of the antennas be manually disconnected at the coaxial bracket and reconnected to the survival transceiver.

#### 2.8.3.4.4 C-Band Beacon Antenna Equipment.

There are four, flush-mounted, C-band beacon antennas located around the perimeter of the S/C near the four S/C axes: +Z, -Z, +Y, and -Y. All four antennas are connected at all times to the C-band transponder equipment with reception by all four antennas. Circuitry in the C-band transponder equipment determines which antenna received the strongest signal and automatically selects that antenna for transmission of response pulses.

#### 2.8.3.5 Electrical Power Distribution.

Electrical power distribution for the voice and data, and the RF equipment groups is shown on sheet 1 of figure 2.8-27. Instrumentation equipment power distribution is shown on sheet 2. Electrical power to most of the equipment on sheet 1 is controlled by the T/C switches on MDC-20. These switches and control circuits can be found on the illustrations for the individual components in paragraphs 2.8.3.3 and 2.8.3.4.

#### 2.8.4 PERFORMANCE AND DESIGN DATA

The following chart contains the a-c and d-c power consumption values for the T/C voice, data, and RF equipment.



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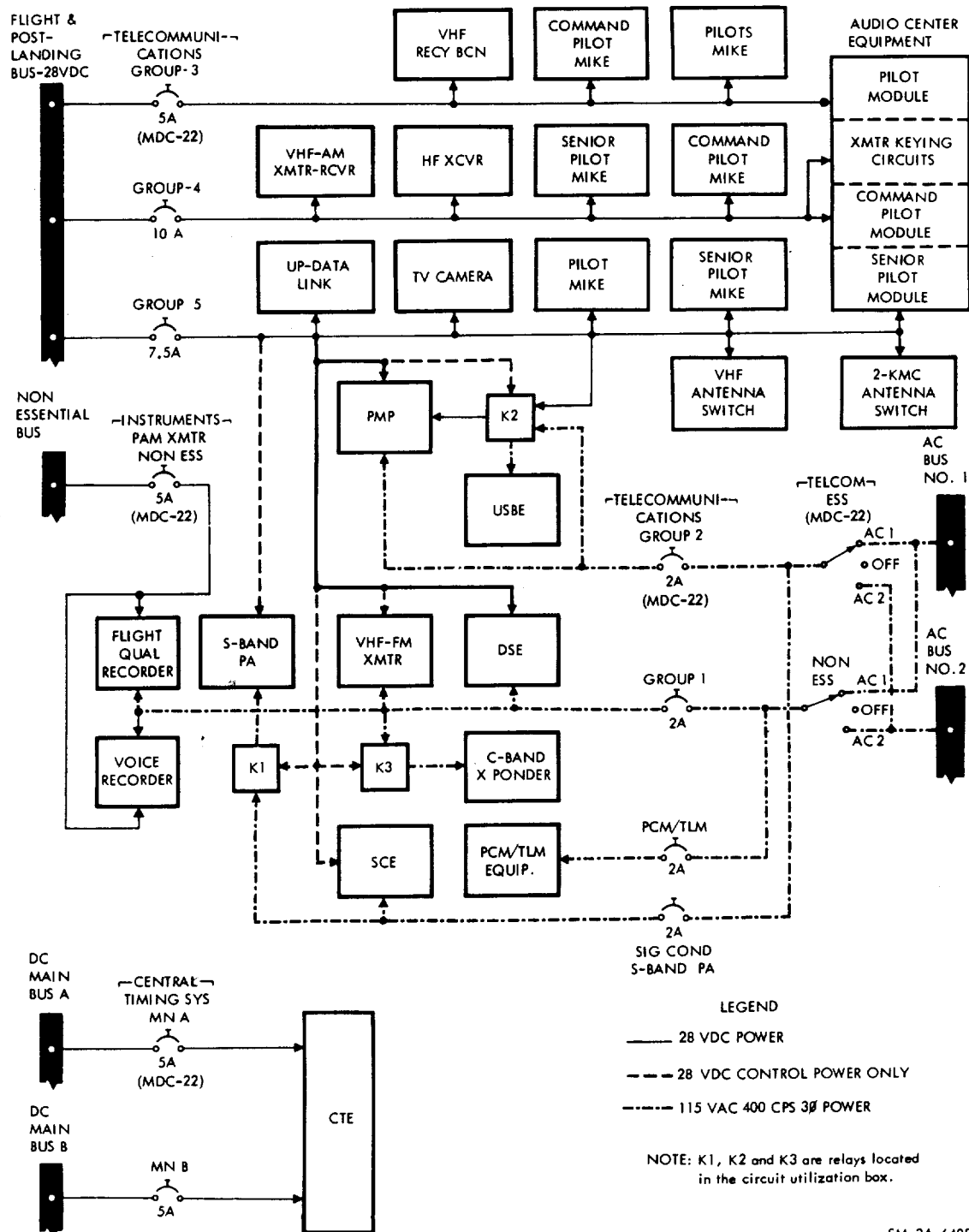
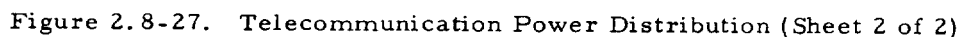


Figure 2.8-27. Telecommunications Power Distribution (Sheet 1 of 2)

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T/C Equipment Power Consumption						
Equipment	Quantity	Control	D-C Watts	A-C Watts	Total	
					D-C Watts	A-C Watts
A-C equipment	3	PWR switch to VOX, MDC (13, 23, 26)	4.3		12.8	
SCE	1	SCE PWR switch ON, MDC 20		45.0		45.0
PCM TLM equipment	1	PCM control button ON, MDC 22		10.5		10.5
TV camera	1	PWR switch ON, TV camera handle	6.0		6.0	
PMP	1	PMP PWR switch ON, MDC 20	2.6	4.0	2.6	6.4
		+ TAPE SWITCH ON, MDC 20	2.6	6.4	2.6	6.4
		EMER VOICE switch ON, MDC 20	3.2		3.2	
		EMER KEY ON, MDC 20	3.6		3.6	
DSE	1	RECORD/PLAYBACK switch other than OFF, MDC 20	0.5	32.5	0.5	32.5
FQR	1	RECORD switch to RECORD MDC 19	34.0	15.0	34.0	15.0
UDL	1	UDL switch to VHF, MDC 20	9.6		9.6	
CTE	1	2-CTE control buttons ON, MDC 22	21.0		21.0	
VHF/AM transmitter- receiver		VHF/AM switch to REC, MDC 20	1.5		1.5	
		VHF/AM switch to T/R, MDC 20	15.5		15.5	
		VHF/AM switch to T/R, PTT button ON, cobra cable MODE switch to PTT	61.5		61.5	
HF transceiver	1	HF POWER switch ON, MDC 20	0.6		0.6	
		HF PWR switch ON, MODE switch to BCN or AM, MDC 20, cobra cable PTT button ON	29.0		29.0	
		HF PWR switch ON, MODE switch to SSB, PTT button on cobra cable ON	40.0		40.0	
VHF/FM transmitter	1	VHF FM switch ON, MDC 20	1.5	50.0	1.5	50.0

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Equipment	Quantity	Control	D-C Watts	A-C Watts	Total	
					D-C Watts	A-C Watts
USBE	1	S-BAND XPONDER switch to XPONDER MDC 20		13.5		13.5
S-band PA	1	S-BAND XPONDER switch to XPONDER PWR AMP, PWR AMP switch LOW, MDC 20	3.0	27.4	3.0	27.4
		S-BAND XPONDER switch to XPONDER PWR AMP, PWR AMP switch HIGH	3.0	80.0	3.0	80.0
C-band transponder	1	C-BAND PWR switch 1 pulse or 2 pulse, MDC 20	3.0	75.0	3.0	75.0
VHF recovery beacon	1	VHF BCN switch ON,, MDC 20	8.0		8.0	
2-KMC antenna switch	1	S-BAND XPONDER switch ON S-BAND switch changed, MDC 20	15.0		15.0	
Voice recorder	1	HF switch and INTER- COM switch to TR, MDC 20; PTT button ON on cobra cable	0.025	1.99	.025	1.99

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2.8.5 OPERATIONAL LIMITATIONS AND RESTRICTIONS.

2.8.5.1 Antennas.

For S-band transmission and reception, the SCIN antenna on the side of the S/C nearest to the MSFN station must be utilized. For VHF transmission and reception, the SCIN antenna indicated in figure 2.8-25 should be utilized. This may require switching between the upper (-Z) and lower (+Z) SCIN antennas while making a single station pass. For VHF operations this must be done manually with the VHF ANTENNA switch. For S-band operations, this can be accomplished either manually or automatically with the S-BAND ANTENNA switch.

At greater slant ranges, null points may exist in the SCIN and C-band beacon overall antenna patterns along the centerline of the S/C, forward and aft of the C/M. Pointing either of these null points at the MSFN station may cause communications to be interrupted.

The lower (+Z) SCIN antenna will be burned off during entry. Thus after entry, the upper (-Z) SCIN antenna or VHF recovery antenna No. 2 must be utilized for communications via the VHF/AM transmitter-receiver.

2.8.5.2 Data Storage Equipment.

a. Maximum DSE running times for the entire reel of tape at the three operating speeds are as follows: 3.75 ips (LOW - 120 minutes, 15 ips (NORM) - 30 minutes, 120 ips (HIGH, for rewind and LBR PCM dump only) - 3.75 minutes.

b. Stored HBR and LBR PCM data, if intermixed on the tape, cannot be dumped within one station pass, due to the different playback speeds required. LBR PCM must be recorded at 3.75 ips and may be played back at 15 ips or 120 ips; HBR PCM must be recorded at 15 ips and played back at 15 ips.

c. Stored PCM TLM need not be played back in the same direction in which it was recorded. Playback in the direction of recording requires rewinding of the tape between recording and dumping.

d. There is no provision for recording TV data.

e. High-bit rate PCM must be recorded at normal speed or tape motion will stop.

f. Low-bit rate PCM must be recorded at low speed or tape motion will stop.

g. If tape is played back at low speed, the tape will move but there will be no playback data available to the transmitters.

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- h. If high-bit rate data is played back at high speed, the transmitter data will be garbled.
- i. If only a FWD or REV command is given to initiate a rewind, there will be no tape motion. A mode (preferably PLAY), must also be selected before tape will move.
- j. Refer to paragraph 2.8.3.2.6 for proper DSE operating functions.

2.8.5.3 Unified S-Band System.

- a. S-band operations will be limited due to the limited number of MSFN stations that will have operational S-band capabilities.
- b. If one of the S-band mode switches (TAPE - OFF - ANALOG or TV - OFF - PLSS) is moved from the OFF position, the FM selection of the S-band transmitter will be selected, reducing the circuit margins and disabling the S-band tracking.
- c. TV can only be transmitted via the USBE.
- d. The secondary oscillator can only be selected in normal operation with the RNG-RNG only switch in the off position and the OSC switch is SEC.
- e. The TAPE and TV switches are 3-position switches with the down position no longer performing valid functions. The down position of these switches should not be selected.
- f. The TAPE and TV switches should never be positioned up simultaneously.
- g. Refer to paragraph 2.8.3.2.5 for valid unified S-band equipment operational modes and their attendant switching configuration.

2.8.5.4 General.

- a. The maximum slant range for reliable VHF-FM TLM communications should not exceed 1500 nautical miles. Also, the maximum elevation angle from the earth to the S/C should not be less than 5 degrees.
- b. Real-time and recorded PCM TLM cannot be transmitted simultaneously. One or the other, however, can be transmitted via the VHF/FM transmitter and the USBs at the same time, and real-time PCM data may be recorded while it is being transmitted.
- c. The FQR has a maximum recording time of approximately 30 minutes. To maintain sufficient time for all scheduled recordings of flight qualification analog data, the FQR must be used conservatively.

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d. When the PCM TLM equipment is operating in the LOW (low bit-rate) mode, approximately 34 percent of the total PCM measurements are available for transmission or storage. Also, many of these measurements are sampled at slower rates.

2.8.6 TELEMETRY MEASUREMENTS.

The following is a complete listing of all T/C telemetry data that is monitored by flight controllers and ground support personnel. The last column contains the name and type of S/C crew display. The display utilizes the same pickoff or signal source as telemetry, unless a separate measurement number is included in the display column. Additional telemetry measurements are found at the end of each system.

An asterisk (\*) by the measurement number denotes information which is not available for recording or telemetry transmission during PCM low bit-rate operation.

Measurement Number	Description	Sensor Range	Crew Display
* CJ 0002 J	Pneum selector sw out sig		None
* CJ 0066 J	EKG axis 1 sel sw out sig	0.1 +5 mv	None
* CJ 0067 J	EKG axis 2 sel sw out sig	0.1 +5 mv	None
CJ 0210 X	Sel sw position ASTRO 1	Event	None
CJ 0211 X	Sel sw position ASTRO 2	Event	None
CJ 0212 X	Sel sw position ASTRO 3	Event	None
CT 0012 X	Tape motion monitor operational	Event	None
CT 0013 X	Tape motion monitor R and D	Event	None
CT 0015 V	Sig cond pos supply volts		None
CT 0016 V	Sig cond neg supply volts		None
CT 0017 V	Sensor excitation 5 volts		None
CT 0018 V	Sensor excitation 10 volts		None
* CT 0055 V	TV camera target voltage		None
* CT 0089 V	C-band XMTR output monitor		None
* CT 0098 V	C-band decoder out		None
CT 0120 X	PCM bit rate change 8 bits	Digital	None
CT 0125 V	PCM HI level 85 percent ref	0 to 5.0 vdc	None
CT 0126 V	PCM HI level 15 percent ref	0 to 5.0 vdc	None
CT 0127 V	PCM LO level 85 percent ref	0 to 0.040 vdc	None
CT 0128 V	PCM LO level 15 percent ref	0.040 vdc	None
CT 0141 X	CTE timing mode monitor	Event	None
CT 0142 F	Central timing GMT 32 bits	Digital	None
CT 0147 V	S-band rec AGC voltage		S-BAND ANT, meter
* CT 0191 V	VHF/AM rec AGC voltage		None
CT 0212 V	S-band RCVR static phase error		None
CT 0215 V	S-band XMTR detected rf output		None
CT 0261 V	UDL receiver signal strength		None
* CT 0262 V	UDL sys validity signal 8 bits	Digital	None
* CT 0320 V	VHF/AM XMTR detected rf output		None
* CT 0330 V	VHF/FM XMTR PA detected rf out		None
CT 0340 X	PCM timing source ext or int	Event	None

TELECOMMUNICATION SYSTEM





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SECTION 2  
SUBSECTION 2.9

SEQUENTIAL SYSTEMS

2.9.1 INTRODUCTION.

The sequential systems consist of control and detection systems which function during ascent and entry portions of a mission or in pre-orbital aborts. The control functions are sensing L/V status, displaying L/V status to the crew, automatically initiating LES aborts in an emergency during early ascent, and automatically sequencing the ELS during descent. Backup controls are provided for critical functions and normal events. The systems are the sequential events control system (SECS), emergency detection system (EDS), launch escape system (LES), and earth landing system (ELS). The systems interface with the reaction control system (RCS), guidance and navigation (G&N), service propulsion system (SPS), stabilization and control system (SCS), electrical power system (EPS), telecommunications (T/C), and controls and displays (C&D).

2.9.2 FUNCTIONAL DESCRIPTION.

The purpose of the sequential systems is to provide safety for the crew during the ascent and descent phases of a mission, and to perform normal separation functions. The EDS monitors operation of the L/V and will initiate an automatic abort in an emergency. The LES is provided for use during an emergency arising from malfunction of the L/V or other systems affecting crew safety. The LES will be utilized to abort the mission in an emergency by separating the C/M from the L/V and S/M. The LES can be operational from the launch pad until the launch escape tower is jettisoned. Following second stage booster ignition, the LES tower is jettisoned from the CSM-L/V combination. The ELS is provided to stabilize and decelerate the C/M following an entry into the earth atmosphere or following an abort. The ELS parachutes will lower the C/M at a suitable velocity and attitude until time of touchdown. A functional description of the sequential systems is contained in the following paragraphs.

2.9.2.1 Sequential Events Control System (SECS).

The SECS consists of controllers (figure 2.9-1) that provide automatic, semiautomatic, and manual control for initiation or termination of functional events during various phases of the Apollo mission. The controllers are the master events sequence controller (MESC), earth landing sequence controller (ELSC), C/M reaction control system controller (C/M RCSC), service module jettison controller (SMJC). Each

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controller consists of redundant relays, timers, and other devices to control systems operation and automatic timing of events. Two controllers are provided in all cases for dual redundancy. The SECS will control the automatically sequenced events during a mission abort, normal CSM-SLA separation, normal C/M-S/M separation, and events during the earth landing phase. The SECS provides conditioned signals to telemetry equipment through the data distribution box so that vital information may be telemetered to MSFN.

The SECS will control the launch escape system (LES) during an abort up to the time of normal launch escape tower jettison. The SPS engine is utilized during an abort after LES tower jettison to propel the CSM away from the L/V. Normal separation of the SLA is performed by the SECS following manual initiation after earth orbit is attained. Emergency separation of the SLA is performed automatically 1.7 seconds after an SPS abort is manually initiated. C/M-S/M separation is performed by the SECS, and is manually initiated during the entry phase or subsequent to an SPS abort. During a LES abort, the C/M-S/M separation is performed automatically by the SECS. Events performed by the earth landing system are automatically controlled by the SECS during normal descent. Switches are provided for manual backup of critical events.

The basic functions performed by the SECS are as follows:

Event	Originates	Function/Input	Manual Control
Auto abort enable	MESC	Lift-off signal	EDS AUTO switch (MDC-16)
LE and PC motors fire	MESC	C/M-S/M separation relays	LES MOTOR FIRE switch (MDC-5)
Pitch motor inhibit	C/M RCSC	Lift-off + 61 seconds	ABORT SYSTEM-OX DUMP switch (MDC-16)
Auto RCS oxidizer dump inhibit	C/M RCSC	Lift-off + 61 seconds	ABORT SYSTEM-OX DUMP switch (MDC-16)
LES tower jettison	MESC	ELS armed and 24K ft baroswitch closure on LES aborts, manual 3 minutes after lift-off	ABORT SYSTEM-MODE switches A and B (MDC-16)
CSM-SLA separation	MESC	Translation control + 1.7 seconds	ADAP SEP switch (MDC-5)

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Event	Originates	Function/Input	Manual Control
RCS/SCS enable	MESC	Adapter separation + 2.5 seconds or C/M-S/M deadface + 1 second	REACTION CONTROL SYSTEM-CMD switch (MDC-16)
LES abort initiation	MESC	EDS abort signal from L/V-IU	Translation control
C/M-S/M separation	MESC	C/M-S/M dead- face relays +0.1 second	C/M-S/M SEP switches A and B (MDC-15)
Canard deploy	MESC	LES abort lockup relays + 11 seconds	CANARD DEPLOY switch (MDC-5)
SPS abort initiation	MESC	Manual	Translation control
RCS/SCS disable	MESC	ELS armed and 24K ft baroswitch closure	REACTION CONTROL SYS-CMD switch (MDC-16)
Apex cover jettison	MESC	ELS armed and 24K ft baroswitch closure +0.4 second	APEX COVER JETT switch (MDC-5)
Drogue parachutes deploy	ELSC	ELS armed and 24K ft baroswitch closure +2 seconds	DROGUE DEPLOY switch (MDC-5)
Drogue parachutes release and main parachutes deploy	ELSC	ELS armed and 24K ft baroswitch closure + 14 seconds + 10K ft baroswitch closure	MAIN DEPLOY switch (MDC-5)
RCS propellants burn	C/M RCSC	Manual	C/M PROP JETT DUMP switch (MDC-8)
RCS purge	C/M RCSC	Manual	C/M PROP JETT PURGE switch (MDC-8)

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Event	Originates	Function/Input	Manual Control
Main parachutes release	ELSC	Manual	MAIN CHUTE release switch (MDC-16)
Postlanding antenna deploy	MESC	Manual	POST LANDING-ANTENNA-DEPLOY switches A and B (MDC-25)

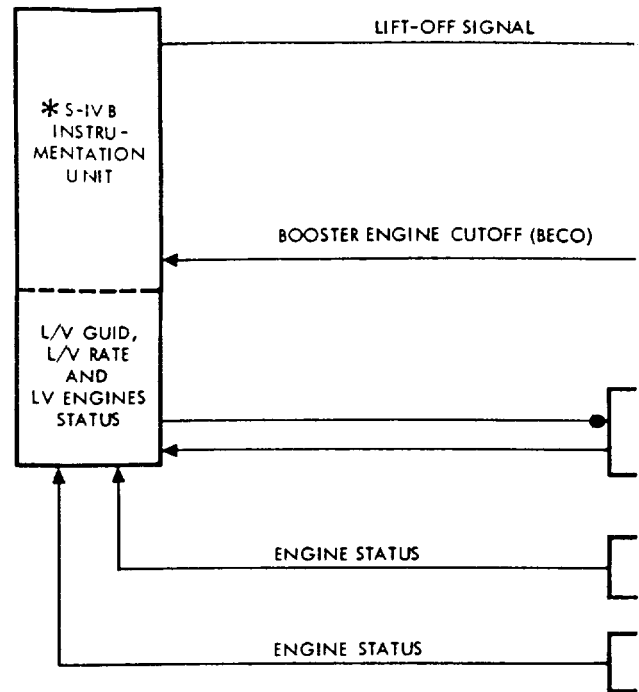
2.9.2.2 Emergency Detection System.

The EDS is designed to detect and display status and emergency conditions of the launch vehicle-spacecraft combination to the astronaut. The EDS also provides automatic abort initiation, under certain conditions, after lift-off up to the normal time of LES tower jettison.

The EDS display circuitry is enabled when the EDS POWER switch (MDC-24) is in the ON position and will illuminate lights on MDC-5 to indicate L/V status. The red L/V RATE light will illuminate when L/V rates are in excess of 20 degrees per second in roll and 5 degrees per second in pitch and yaw. The rates are sensed by three rate gyros mounted on each L/V axis in the instrumentation unit (IU). The red L/V GUID light (MDC-5) illuminates to indicate failure of the guidance unit which is also located in the instrumentation unit. The yellow L/V ENGINES lights (MDC-5) illuminate when a respective S-I booster engine is developing less than 90 percent of total thrust output. The L/V ENGINES lights are monitored for engine status during thrusting periods. During staging, the L/V ENGINES lights are monitored for illumination to indicate BECO and extinguish to indicate stage separation. After staging, the number 1 L/V ENGINE light indicates the status of the S-IVB Stage engine, it will be extinguished when the engine is producing 65 percent rated thrust. The ABORT light (MDC-3) is a red lamp assembly containing 4 bulbs. Two bulbs are in system A and two bulbs are in system B for redundancy. The ABORT light is illuminated if an abort is requested by launch control center for a pad abort or an abort during lift-off via radio. The ABORT light can be illuminated after lift-off by the Range Safety Officer transmitting a destruct arm command. The destruct arm command will also initiate BECO. An abort may also be requested via radio from the MSFN after lift-off +10 seconds.

The EDS automatic abort circuitry is enabled at lift-off providing the EDS AUTO switch (MDC-16) is in the AUTO position. (See figure 2.9-2.) A circuit is completed through the lift-off enable and first motion relays at lift off. The lift-off enable relays are latching

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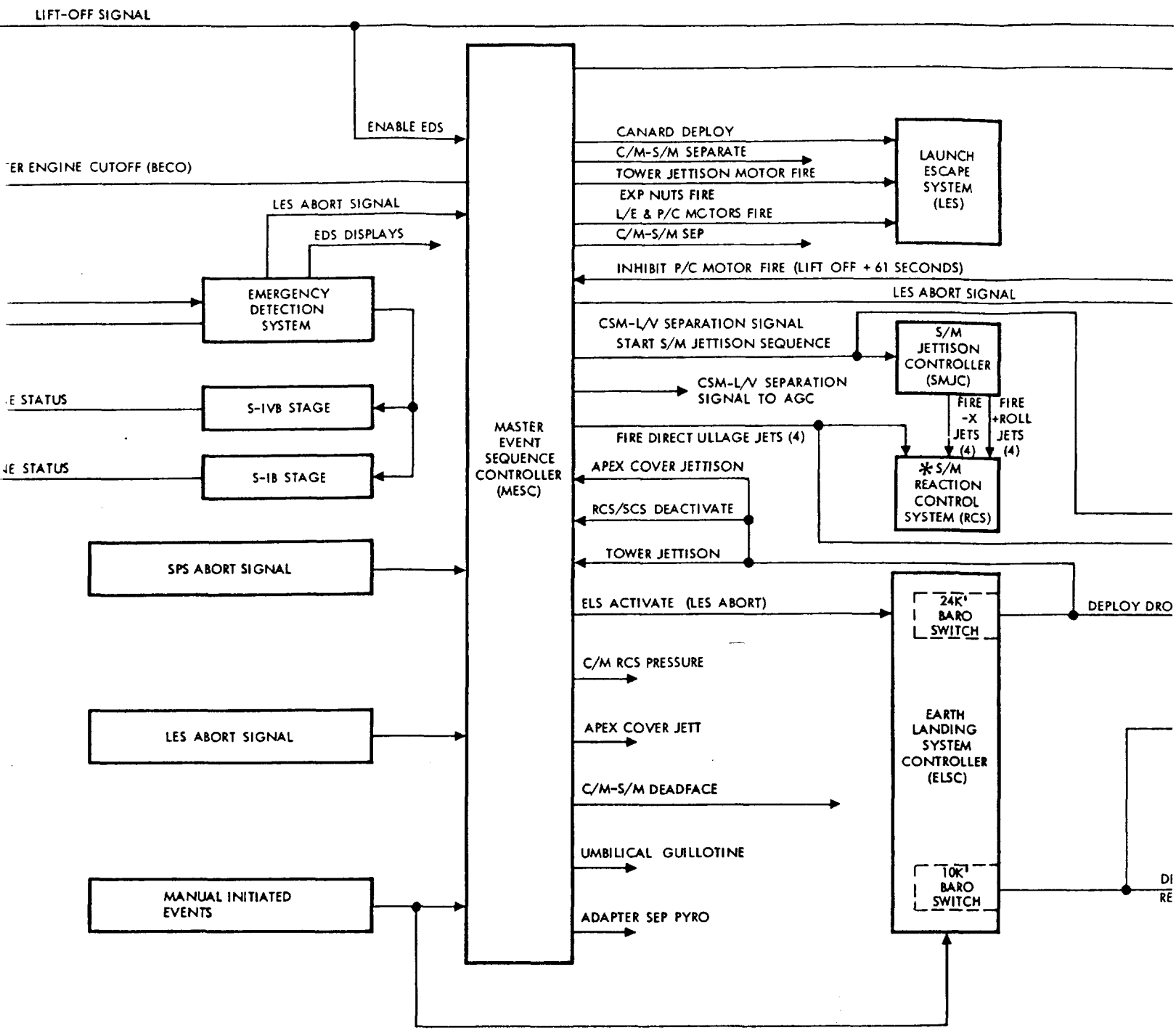


SPS ABO

LES ABO

MANUAL  
EVENTS



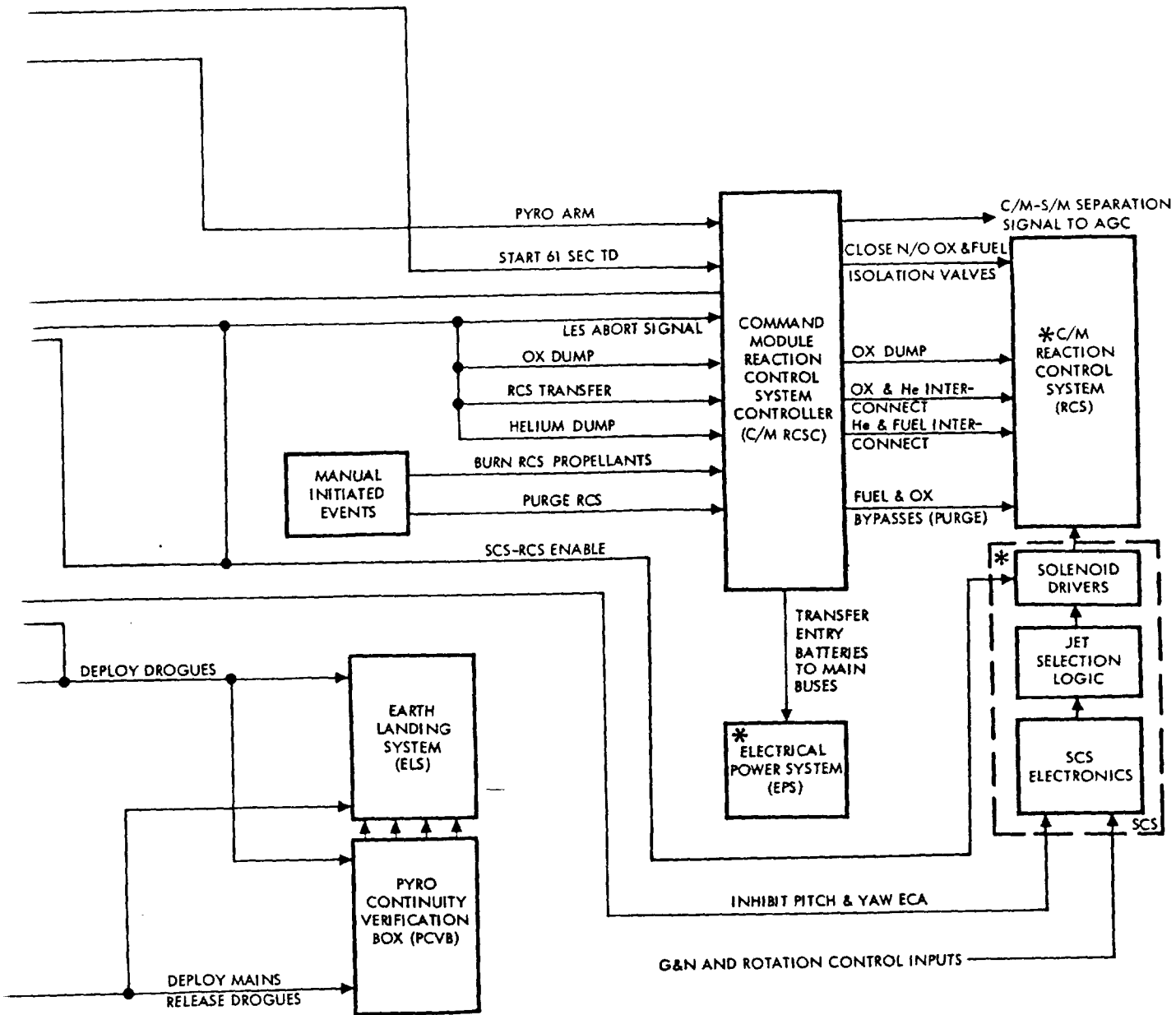


**WOLDOUT FRAME 2**





SYSTEMS DATA



\* NOT PART OF SECS (INTERFACE).

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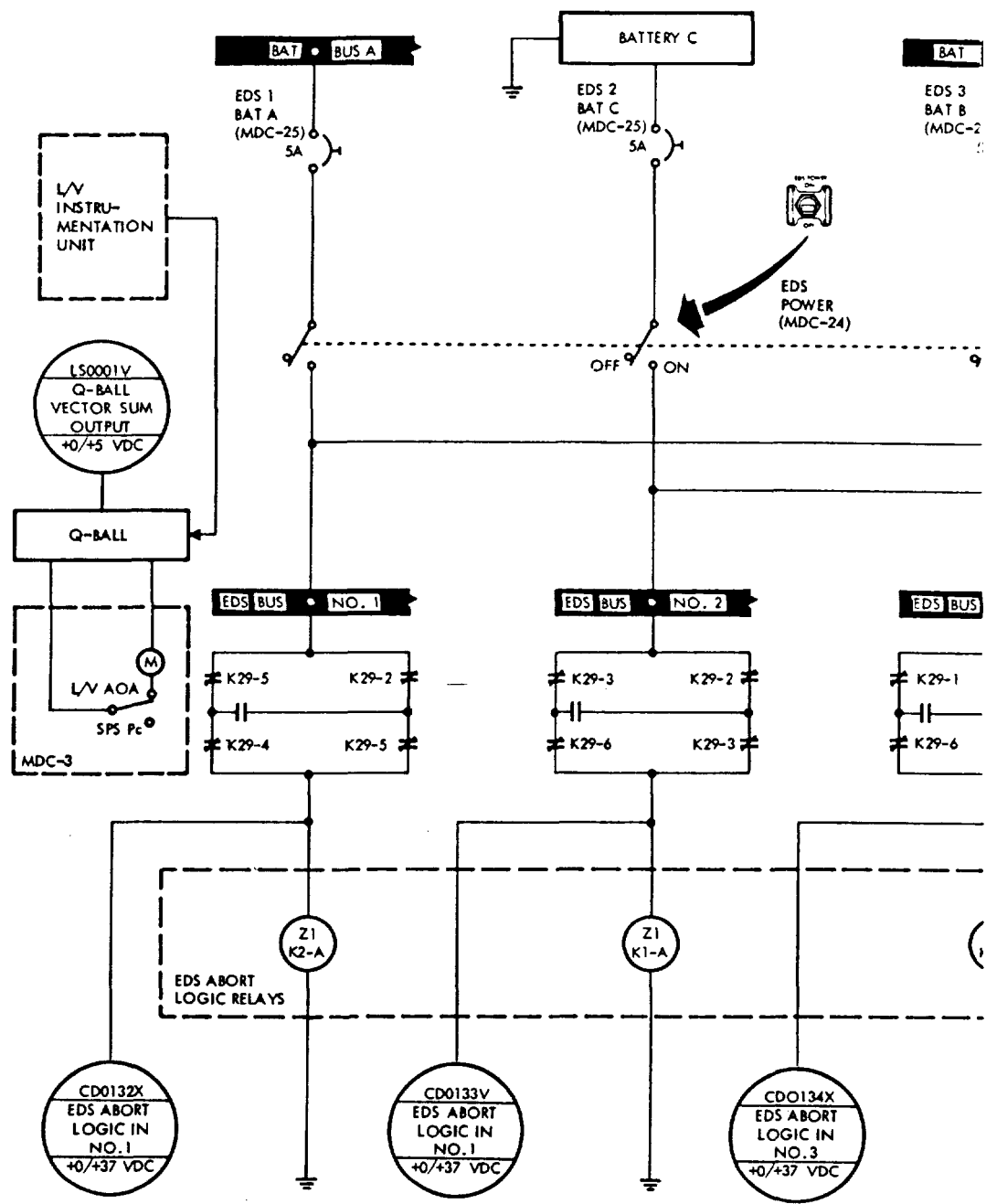
Figure 2.9-1. SECS Controllers Interface Block Diagram

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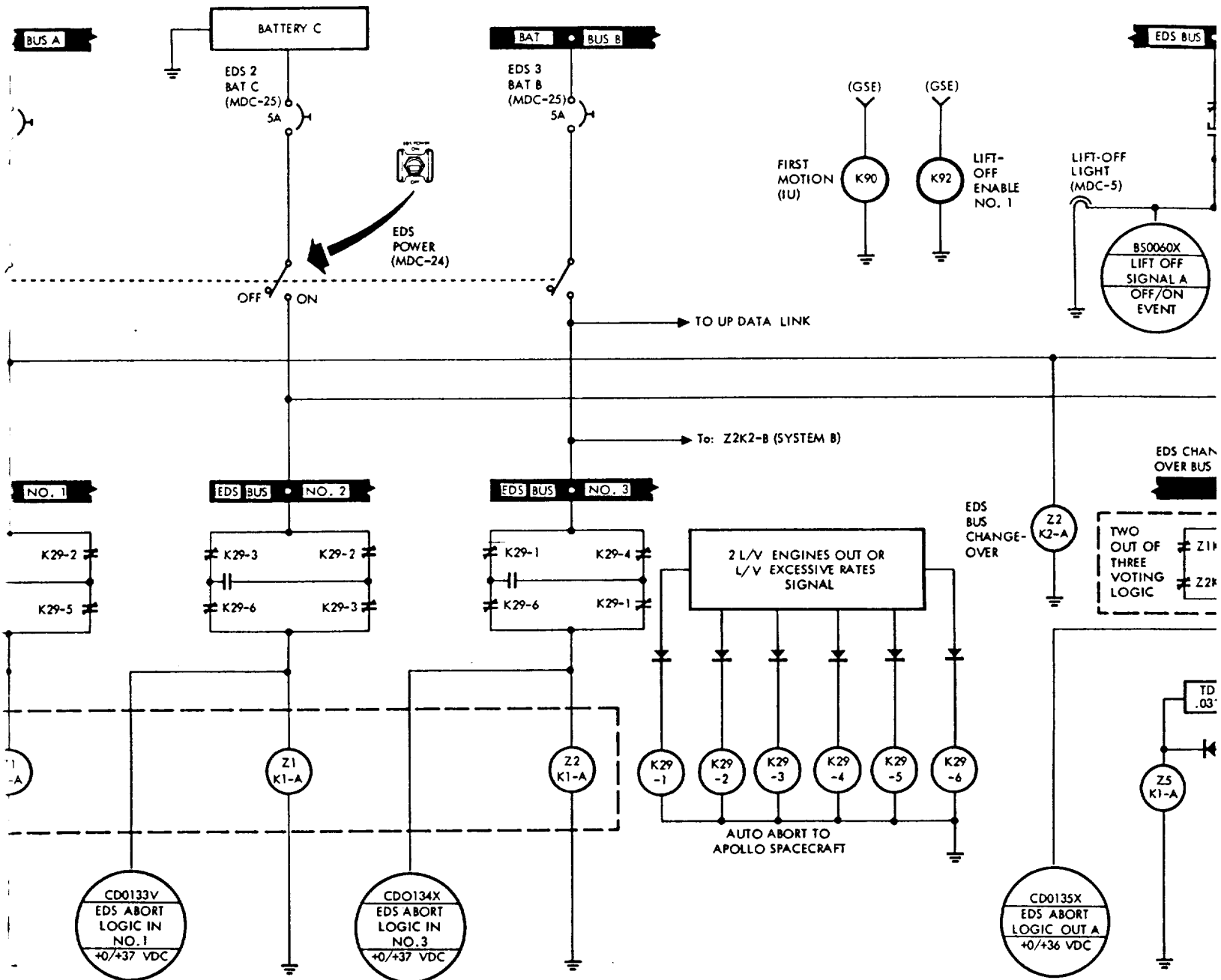




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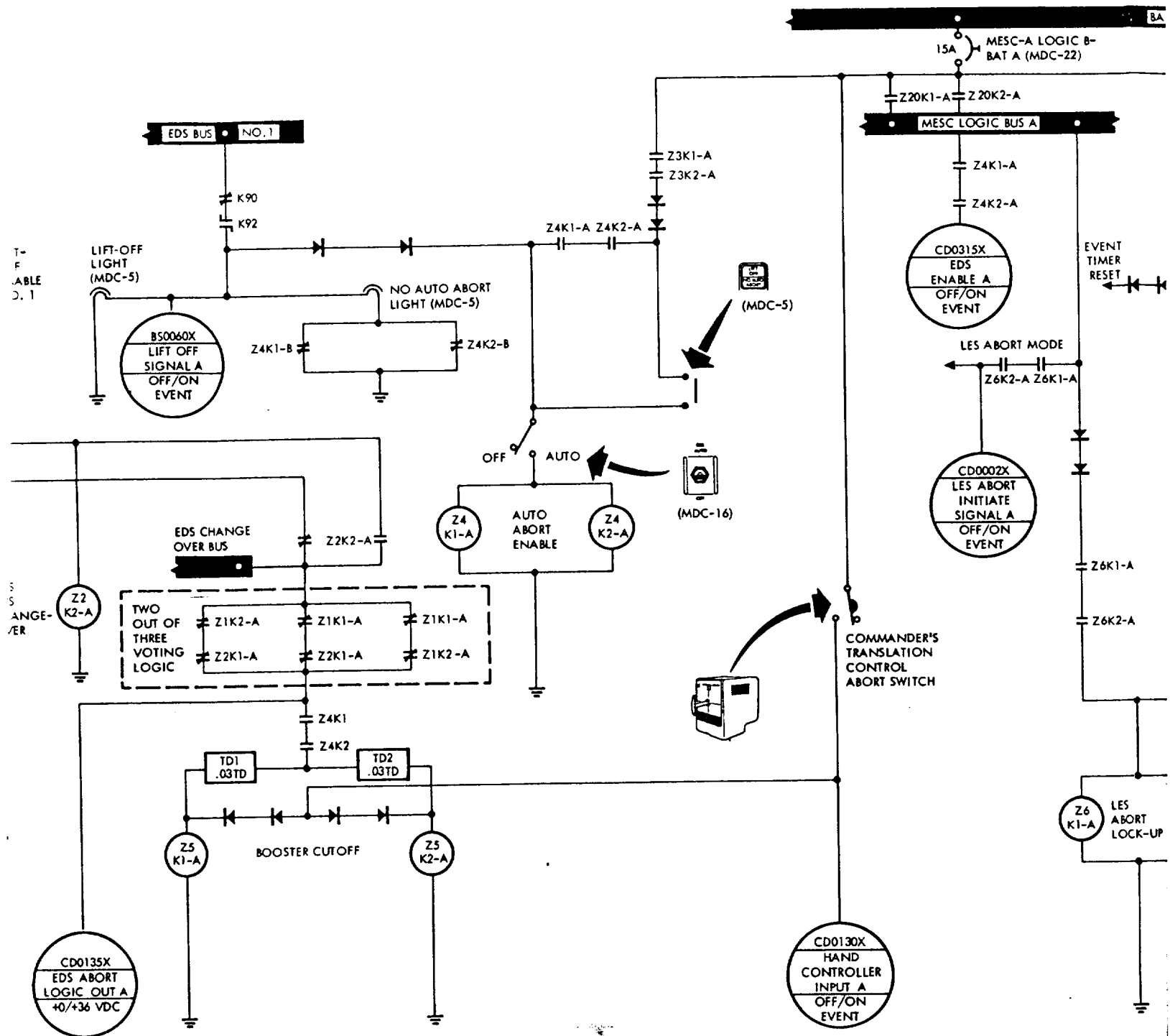
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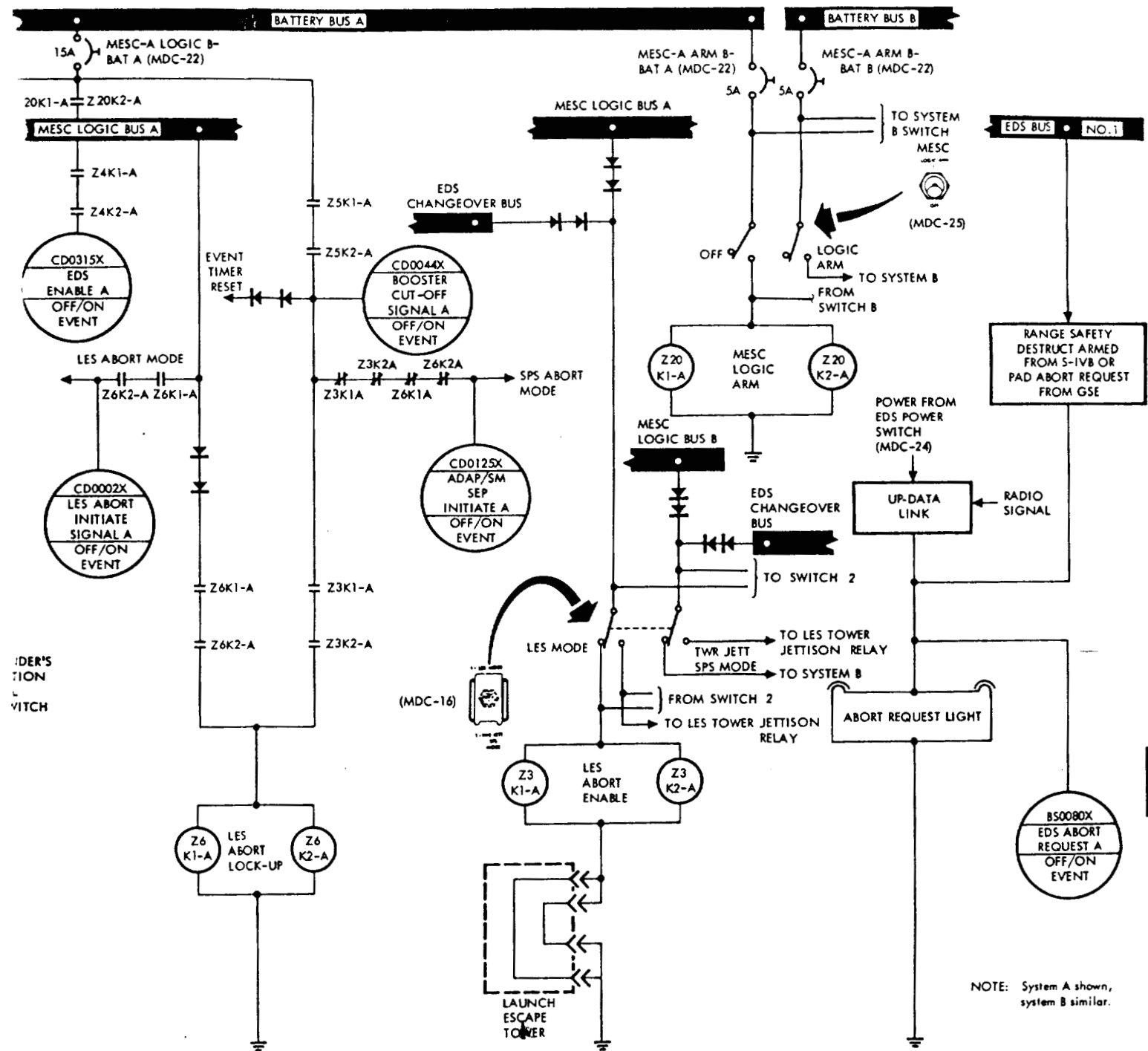


Figure 2.9-2. EDS Functional Schematic

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type and are latched closed by GSE just prior to lift-off. The normally closed first motion relays remain energized by GSE until actual lift-off occurs. A circuit is completed through the relays and the EDS AUTO switch upon lift-off. The white LIFT-OFF light (MDC-5) illuminates and the red NO AUTO ABORT light (MDC-5) should remain extinguished. The astronaut presses the NO AUTO ABORT switch-light if it illuminates. The NO AUTO ABORT switch-light should also be pressed if the LIFT OFF light does not illuminate at lift-off. This would indicate that the circuit was not completed for illuminating the LIFT OFF light and energizing the auto abort enabling relays. Pressing the NO AUTO ABORT switch-light will energize the auto abort enabling relays through circuitry in the MESC. The EDS AUTO switch must be at AUTO to complete the circuit. The LIFT OFF light would not illuminate in this case. (Refer to Malfunction Procedures in section 9.) The LIFT OFF light is extinguished by circuitry in the L/V IU at approximately 5 seconds after illumination at lift-off. The EDS will automatically initiate an abort when two L/V engines fail or L/V excessive rates are sensed if these two functions are enabled. The two functions are enabled with the ABORT SYSTEM - 2 ENG OUT switch (MDC-16) and ABORT SYSTEM - RATES switch (MDC-16). The two switches are set to off to inhibit the two functions prior to S-IB staging. L/V guidance failure will not initiate an automatic abort. The crew will contact MSFN and a decision made on the action to be taken. If a destruct arm command is transmitted prior to inhibiting the two-engine out auto abort capability, the EDS will detect BECO and initiate an automatic abort. If a destruct arm command is transmitted after the two-engine out auto abort capability is inhibited, a manual abort must be initiated immediately when the ABORT light illuminates. Structural breakup or separation of the structure between the IU and C/M will also be detected by the EDS and an automatic abort initiated. During ascent on a normal mission, the EDS AUTO switch must be set to OFF prior to launch escape tower jettison. Inhibiting of the auto abort capability ensures that an automatic abort can not be initiated at the same time that the launch escape tower is being jettisoned. An abort may be initiated manually by rotating the commander's translation control to the counterclockwise detent position (20 degrees).

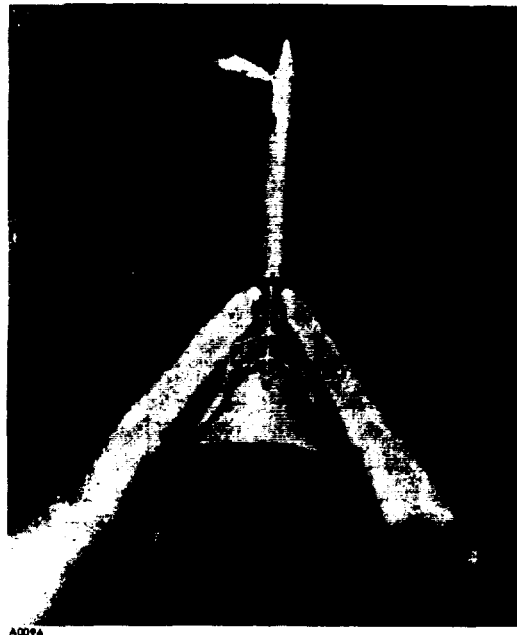
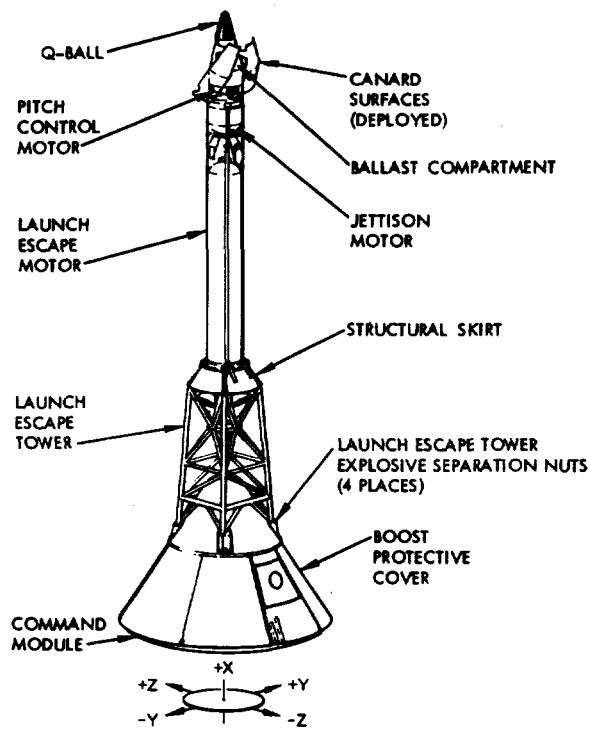
The parameters being sensed by the EDS are extremely time-critical at various periods during the boost phase. When these parameters are exceeded, an LES abort is automatically initiated to propel the escaping vehicle (C/M and LES) safely away from the launch vehicle prior to a catastrophic condition. Concurrently with abort initiation, either automatically or manually, logic circuitry will shut down engines in the L/V activate stage. The engine shutdown signal is inhibited by circuitry in the IU for the first 40 seconds of launch because of range safety restrictions.

A Q-ball (figure 2.9-3) mounted above the LES motors, provides an electrical signal input to the L/V AOA/SPS  $P_c$  indicator on MDC-3 and an electrical signal input to ground control via telemetry.

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Figure 2.9-3. Launch Escape System

The Q-ball has four static ports for measuring  $\Delta P$  which is a function of angle of attack. The  $\Delta P$  is related to pitch and yaw, and is electronically analyzed and displayed on the L/V AOA SPS  $P_c$  indicator on MDC-3. The indicator is graduated to 150 percent because of start transients of the SPS. The indicator is monitored for the L/V AOA function from 40 seconds after lift-off until approximately one minute and 40 seconds.

Position of the red line is based on vehicle structural limits and launch vehicle capabilities. A decision for manual abort initiation will be made when the indicator pointer reaches the red line and a movement is also observed on the FDAI.

### 2.9.2.3 Launch Escape System.

Purpose of the LES (figure 2.9-3) is to provide immediate abort capabilities from the launch pad to the normal time of LES tower jettison. The ABORT SYSTEM - MODE switches 1 and 2 (MDC-16) are in the LES MODE position prior to LES tower jettison, and an abort will be accomplished by utilizing the launch escape system. A manual or

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automatic initiated abort signal will activate a master event sequence controller (MESC). The MESC will initiate C/M-S/M separation, and ignite the launch escape and pitch control motors. Firing of the pitch control motor is automatically inhibited 61 seconds after lift-off by a time-delay relay. The LES motors provide sufficient thrust for the lift and lateral translation of the C/M away from the launch pad, or trajectory of the launch vehicle. Two canard surfaces (figure 2.9-3) are deployed 11 seconds after abort initiation to orient the C/M to a blunt-end-forward attitude. (Refer to Abort Procedures in section 9.)

During a normal mission, the LES tower is jettisoned shortly after second stage booster (S-IVB) engine ignition. LES tower jettison is manually initiated approximately 3 minutes after lift-off by setting the ABORT SYSTEM - MODE switches 1 and 2 (MDC-16) to the TWR JETT SPS MODE position. Either switch will enable systems A and B of the redundant circuitry. Both switches should be set at the same time. Any abort, after LES tower jettison, must be accomplished in the SPS mode by utilizing the SPS engine. (Refer to Abort Procedures in section 9.)

A boost protective cover (BPC) completely covers the conical section of the command module. The cover protects the command module and windows from heating during the ascent phase, and soot at launch escape tower jettison in the event of an abort. The cover is attached to and is jettisoned with the LES tower. A removable section allows access to the C/M crew compartment. The cover has one window fabricated of fused silica glass and is located over the forward viewing window.

2.9.2.4 Earth Landing System.

The ELS provides for safe return of the command module and crew following an earth orbital mission, a lunar mission, or mission abort. The ELS consists of two earth landing system controllers (ELSC) and parachutes. The ELS logic circuitry is armed automatically during an abort in the LES mode, and is armed manually with the ELS LOGIC switch on MDC-8 during a SPS abort or normal entry. The ELSC contains baro switches and time-delay relays. After the logic circuitry is armed, the ELSC automatically senses altitude and initiates deployment of the parachutes at the proper time. The time-delay relays control initiation of automatic events after the 24,000 feet baro switch closes. The parachutes (figure 2.9-4) are located in the forward compartment of the C/M, under the apex cover. During a normal entry or descent from an abort initiated above 30,000 feet, the 24,000 feet baro switch closes and completes a circuit to the MESC which jettisons the launch escape tower. The MESC initiates apex cover jettison 0.4 seconds after launch escape tower jettison. Closing of the 24,000 feet baro switch completes a circuit to a 2-second time delay and a 14-second time delay to jettison the drogue parachutes in 2 seconds. The 14-second time delay completes a circuit to the 10,000 feet baro switch.

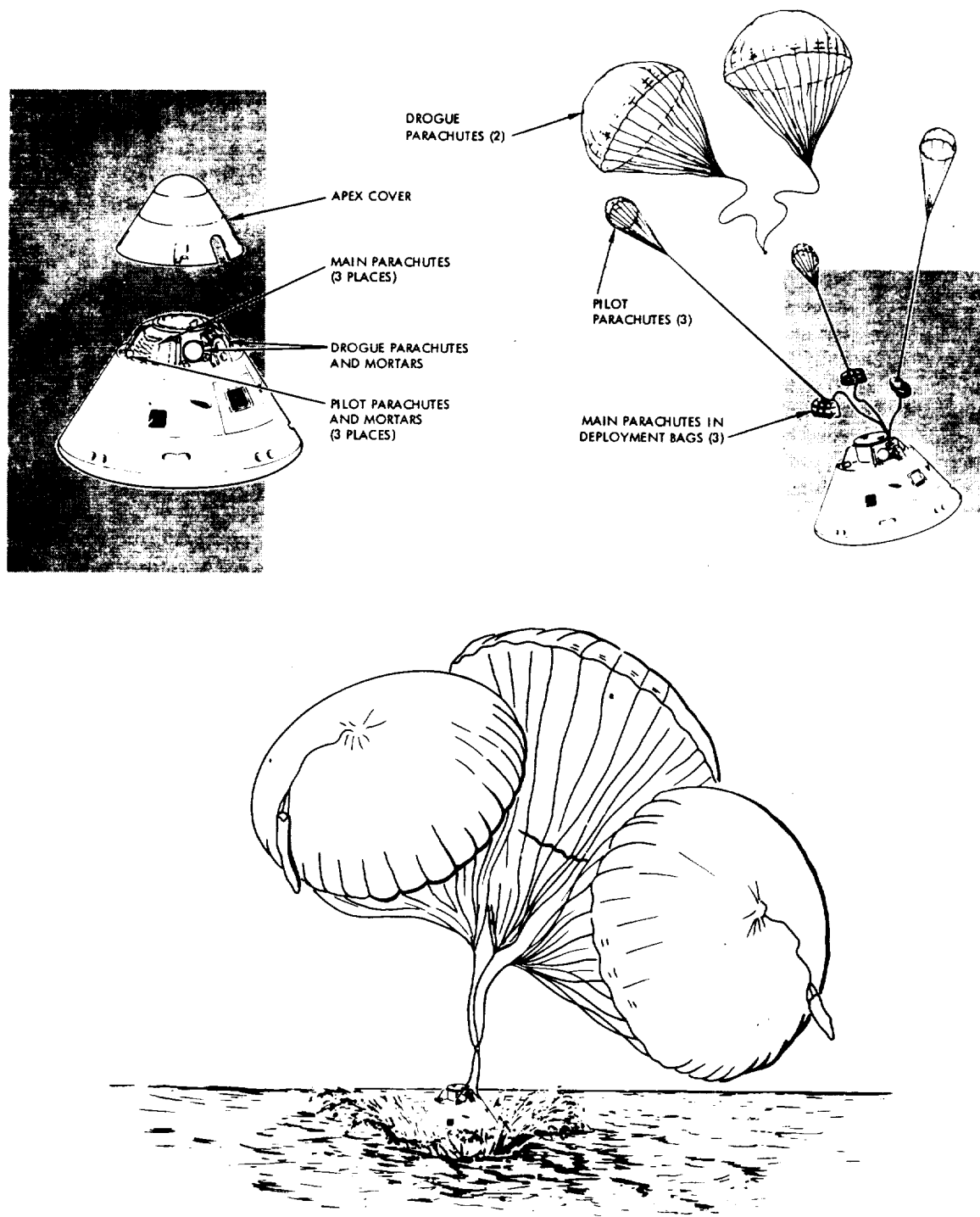
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Figure 2.9-4. ELS Parachute Equipment

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The drogue parachutes are held in a reefed condition for 8 seconds by two reefing lines. Each reefing line has two reefing line cutters. A pyrotechnic time-delay train in each reefing line cutter is ignited at the time of drogue parachute line stretch, causing automatic disreefing after 8 seconds. The drogue parachutes remain attached to the command module until descent to approximately 10,000 feet where the 10,000 feet baro switch closes to initiate drogue parachute disconnect. Simultaneously with drogue parachute disconnect, three pilot parachutes are independently mortar deployed, which removes the main parachute packs from the C/M and extracts the main parachutes from their deployment bags. The main parachutes are reefed for 8 seconds. Disreefing then occurs, and the parachutes fully inflate to lower the C/M safely to landing. Three reefing line cutters are employed on each of the two reefing lines for the main parachutes.

A 27-1/2-degree hang-angle of the C/M is maintained by means of the main parachutes attachment. The hang-angle contributes to the crew tolerance impact by ensuring that impact occurs at the specifically designed C/M structural attenuation point. This attenuation point is on the +Z-axis.

Special note should be made that the apex cover jettison and deployment of the drogue parachutes may be manually initiated at 45,000 feet during a normal entry if the flight characteristics of the command module become unstable. (Refer to operational limitations and restrictions.)

An ELS - AUTO/MAN switch (MDC-16) is provided for the crew to inhibit automatic deployment of the main parachutes during a low-altitude abort initiated prior to 61 seconds after lift-off. The switch is set to the AUTO position prior to launch. In the event of an abort prior to 61 seconds after lift-off, the crew will set the switch to MAN after drogue parachute deployment if the C/M is above an altitude of 3300 feet. Deployment of the main parachutes will be manually initiated by pressing the MAIN DEPLOY switch on MDC-5, when the altimeter pointer reaches the adjustable marker setting (3300 feet) on the altimeter face. This action will preclude the possibility of the command module drifting back on a land area. The ELS switch should be returned to AUTO after the main parachutes are deployed. This will allow a 14-second time delay to time out and permit release of the main parachutes when the MAIN CHUTE RELEASE switch is actuated after touchdown.

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The postlanding recovery aids consist of a sea dye marker, swimmers umbilical, C/M vent fan, C/M uprighting system, HF recovery antenna, and a flashing beacon light. The sea dye marker and swimmers umbilical are deployed automatically when the recovery antenna is deployed. The marker and swimmers umbilical are tethered to the C/M forward compartment deck. The sea dye marker will last approximately 12 hours. The C/M vent fan (part of the ECS) is turned on after landing to vent the C/M to the outside atmosphere. The C/M uprighting system is activated only if the C/M is in a stable inverted attitude. (Refer to Command Module Uprighting System in section 2.)

The flashing beacon light and two VHF antennas located on the forward compartment deck on the C/M are automatically deployed to an upright position after main parachute deployment. The risers of the main parachutes actuate reefing line cutters, which cut retention ties and allows the beacon light and VHF antennas to be extended in 8 seconds. The beacon light has a self-contained power supply capable of operating the light for three 8-hour duty cycles. The flash rate is 15 per minute at an intensity of 1.2 candle-seconds per flash.

The postlanding control switches are located on MDC-25. A recovery pickup cable is provided on the command module for retrieval by recovery forces.

2.9.3 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

Each of the sequential systems employ redundant circuits for reliability. Seven batteries are provided in the spacecraft to furnish electrical power for the spacecraft portion of the systems during operation. Entry batteries A, B, and C, and two pyro batteries are located in the command module, and two S/M jettison batteries are located in the service module. Entry batteries A, B, and C are the only batteries that are rechargeable during the mission.

Entry batteries A and B furnish power for the EDS displays and MESC logic circuitry. The pyro batteries furnish power for detonation of pyrotechnic devices during aborts, separation functions, and parachute operation during the normal landing sequence. (See figure 2.9-5 for a C/M battery bus tie-in schematic.) A description of each of the sequential systems is contained in the following paragraphs.

2.9.3.1 Sequential Events Control System.

The SECS consists of two master events sequence controllers (MESC), two earth landing sequence controllers (ELSC), two command

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module reaction control system controllers (C/M RCSC), and two service module jettison controllers (SMJC). The SMJC is located in the service module. All other controllers are located in the command module. Each controller consists of relays, timers, and other devices to provide automatic and semiautomatic control of the systems.

Many operations in the SECS are accomplished by pyrotechnic devices of various types. Apollo standard initiators (ASI) are used

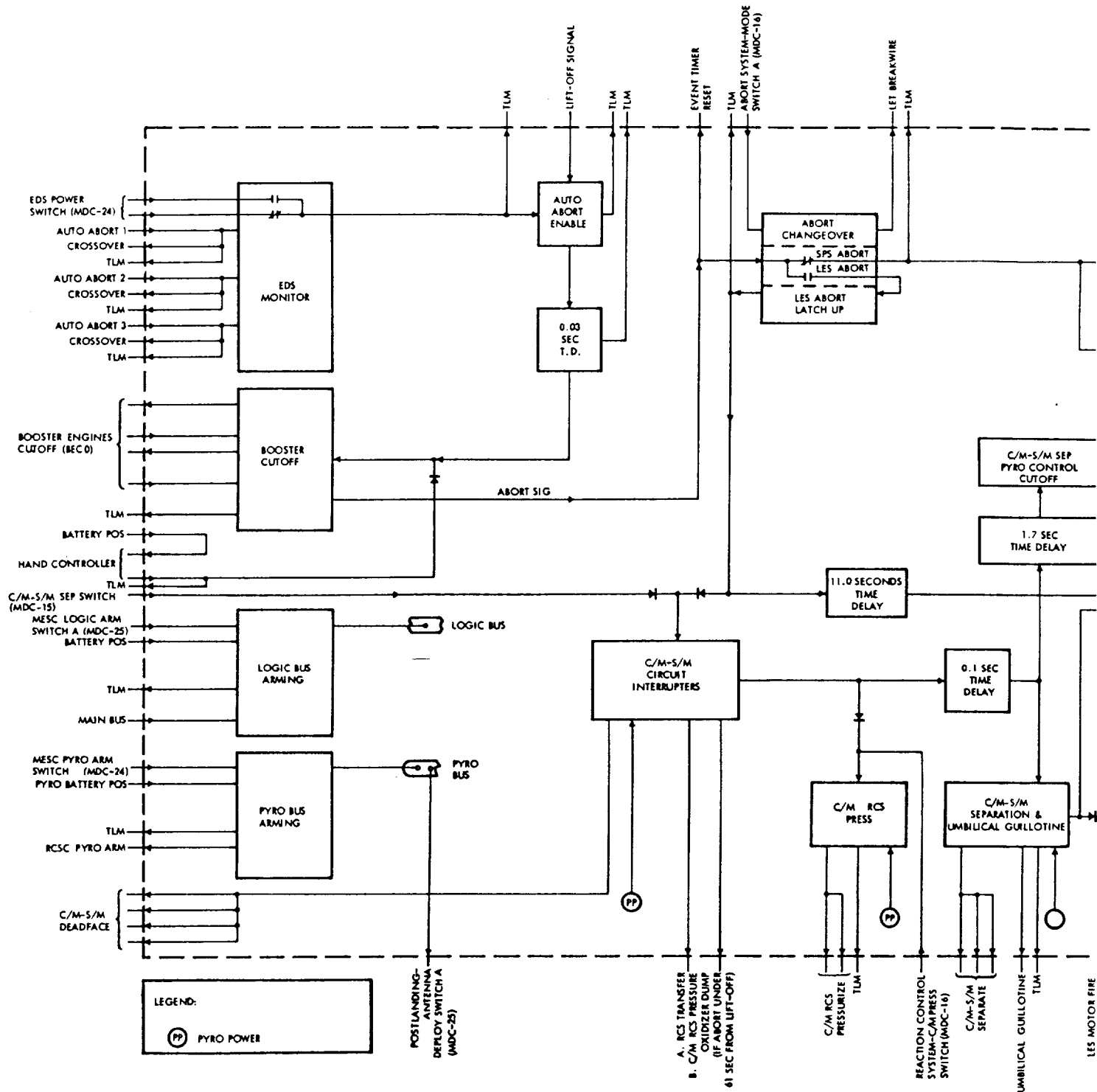
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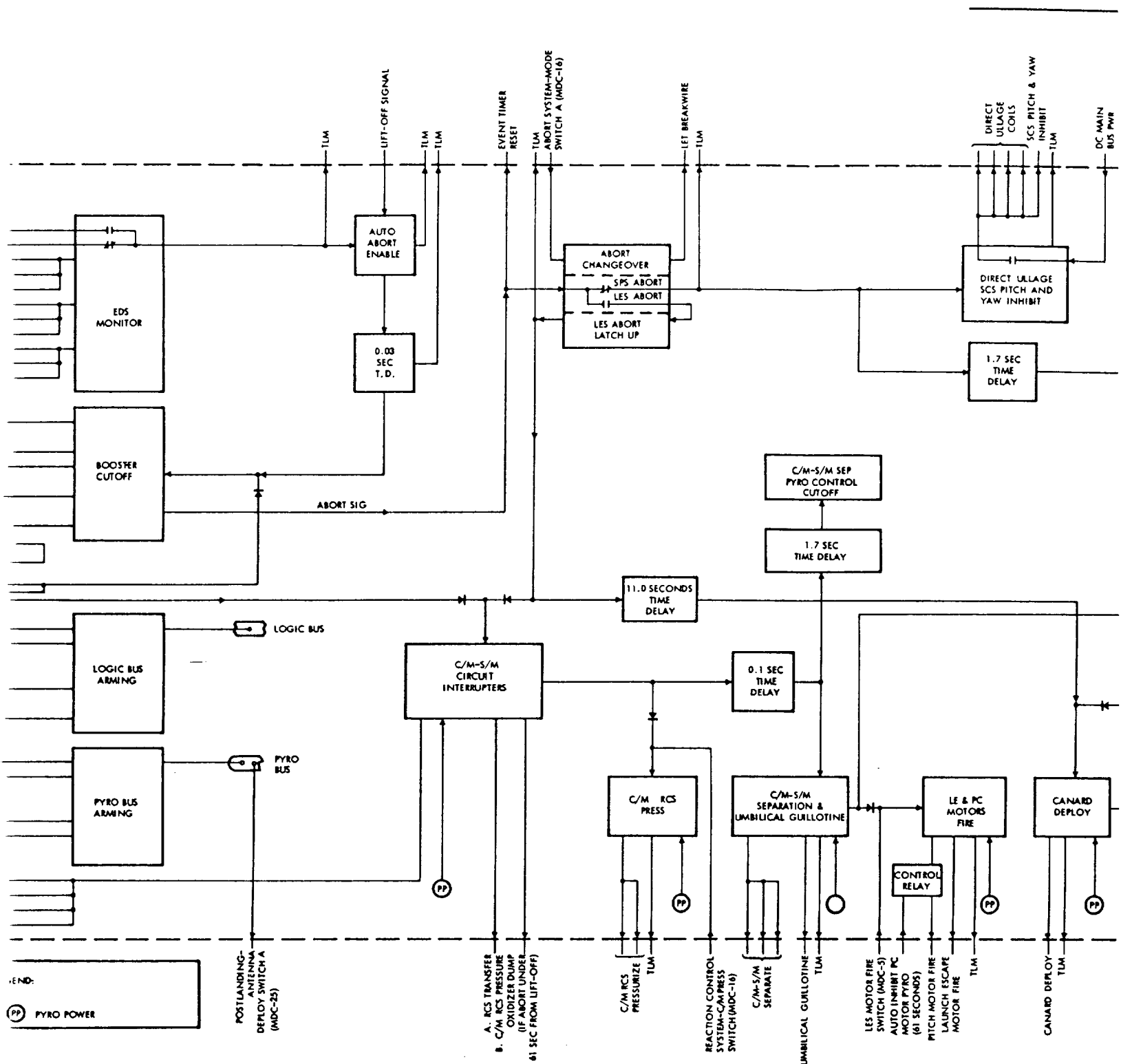
Function and Pyro Device	Normal Actuating Control	Backup Control
b. C/M-RCS pressurizing valves c. Circuit interrupters d. C/M-S/M umbilical guillotine e. LE and Pc motors igniter cartridges LE tower (TWR) jettison a. TWR to C/M attaching nuts (explosive) b. TWR jettison motor igniter cartridges Postlanding antenna deploy	Automatic signal from MESC or manual control from ABORT SYSTEM - MODE switches 1 and 2  Manual actuation of POSTLANDING - DEPLOY switches 1 and 2 (MDC-25)	ABORT SYSTEM - MODE switches 1 and 2 (MDC-16)

2.9.3.1.1 Master Events Sequence Controllers (MESC).

The MESC (figure 2.9-6) provides the logic and timing to initiate and terminate events associated with the ascent and abort modes. Controller A is in system A and controller B is in system B of the redundant systems. Crossover circuitry between controllers A and B ensures correct outputs for detonating pyrotechnic devices even if one redundant circuit is inoperative. The logic circuitry is armed with the two MESC-LOGIC ARM switches 1 and 2 on MDC-25. The pyro circuitry is armed with the two MASTER EVENT SEQ CONT-PYRO ARM switches 1 and 2 on MDC-24. Backup controls are provided for most of the events controlled by the MESC







Figure

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BOLDOUT FRAME 2



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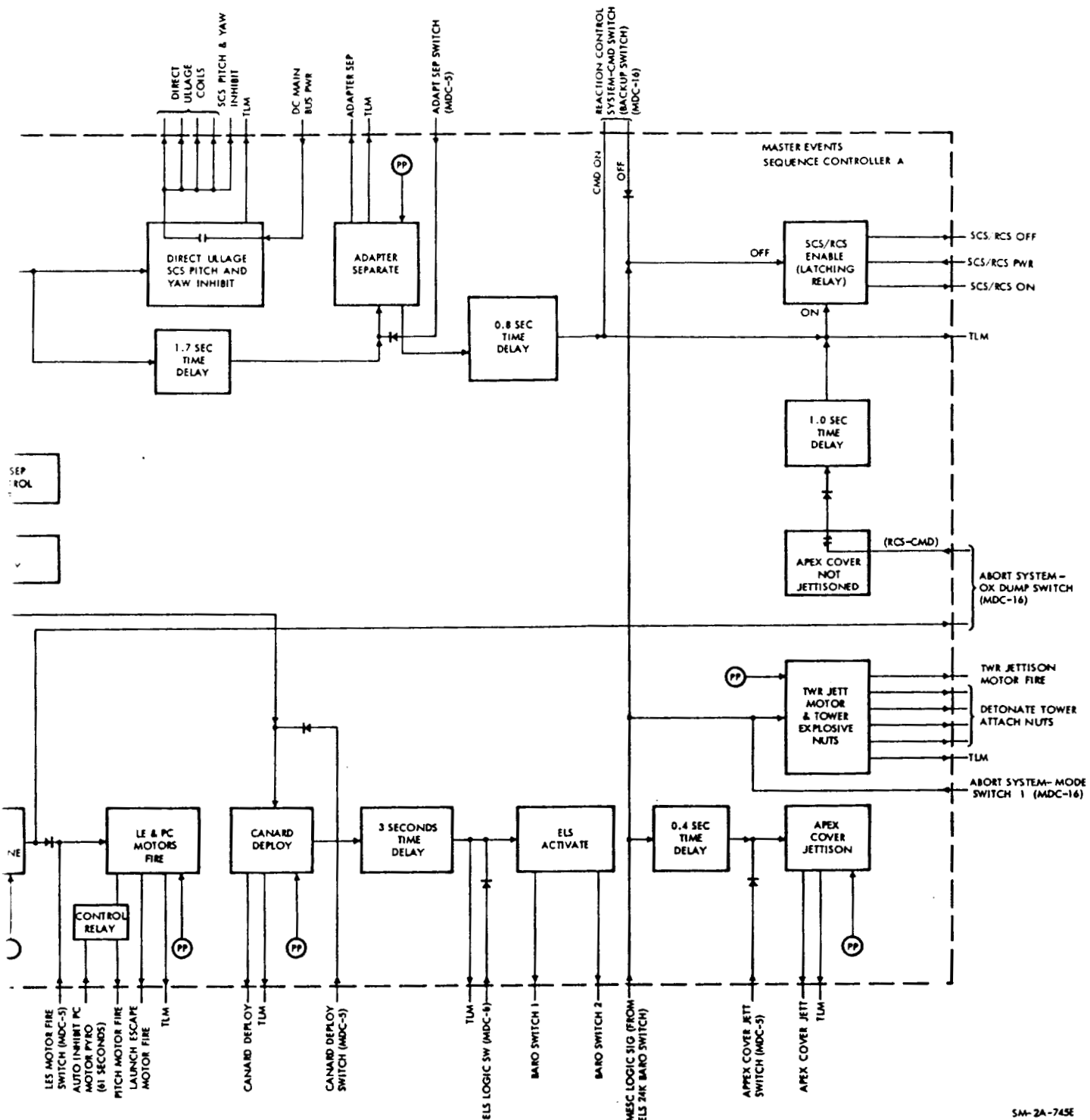
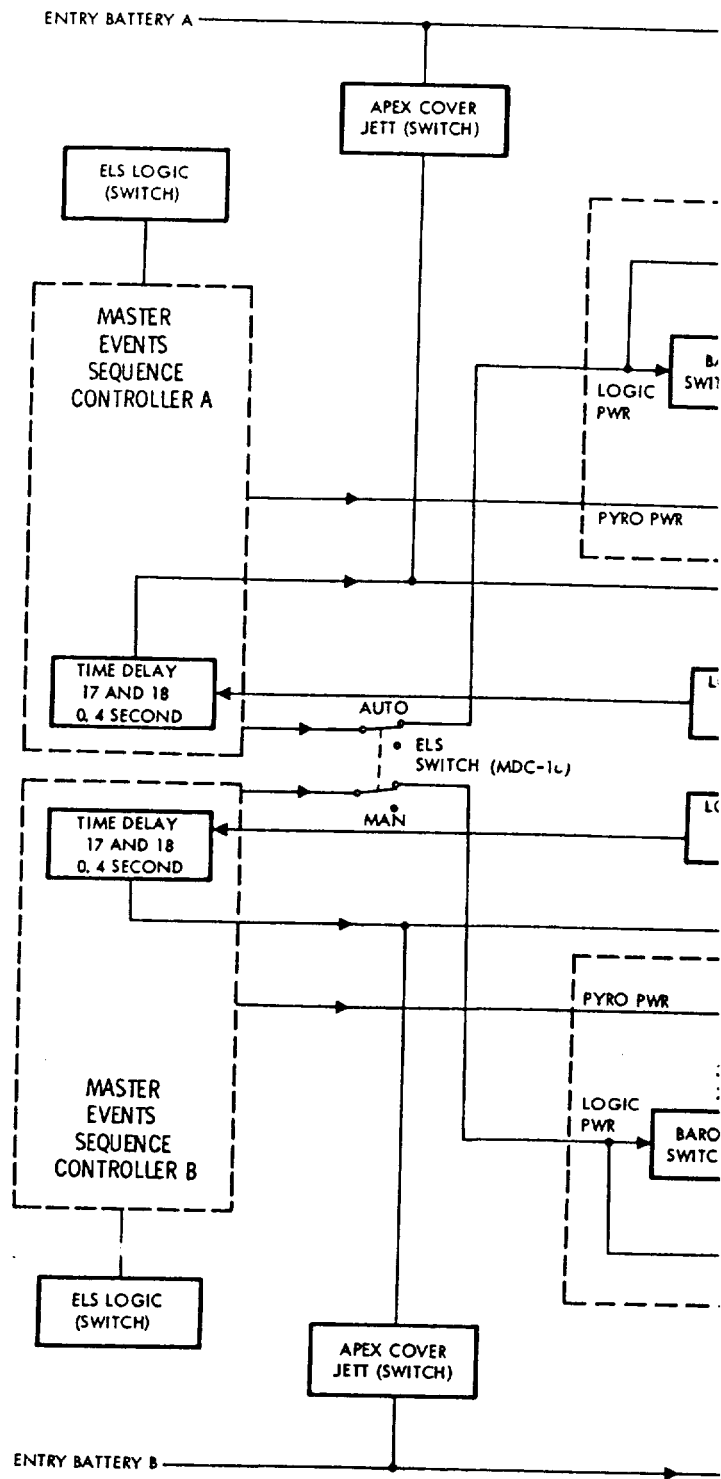


Figure 2.9-6. Master Events Sequence Controller Block Diagram

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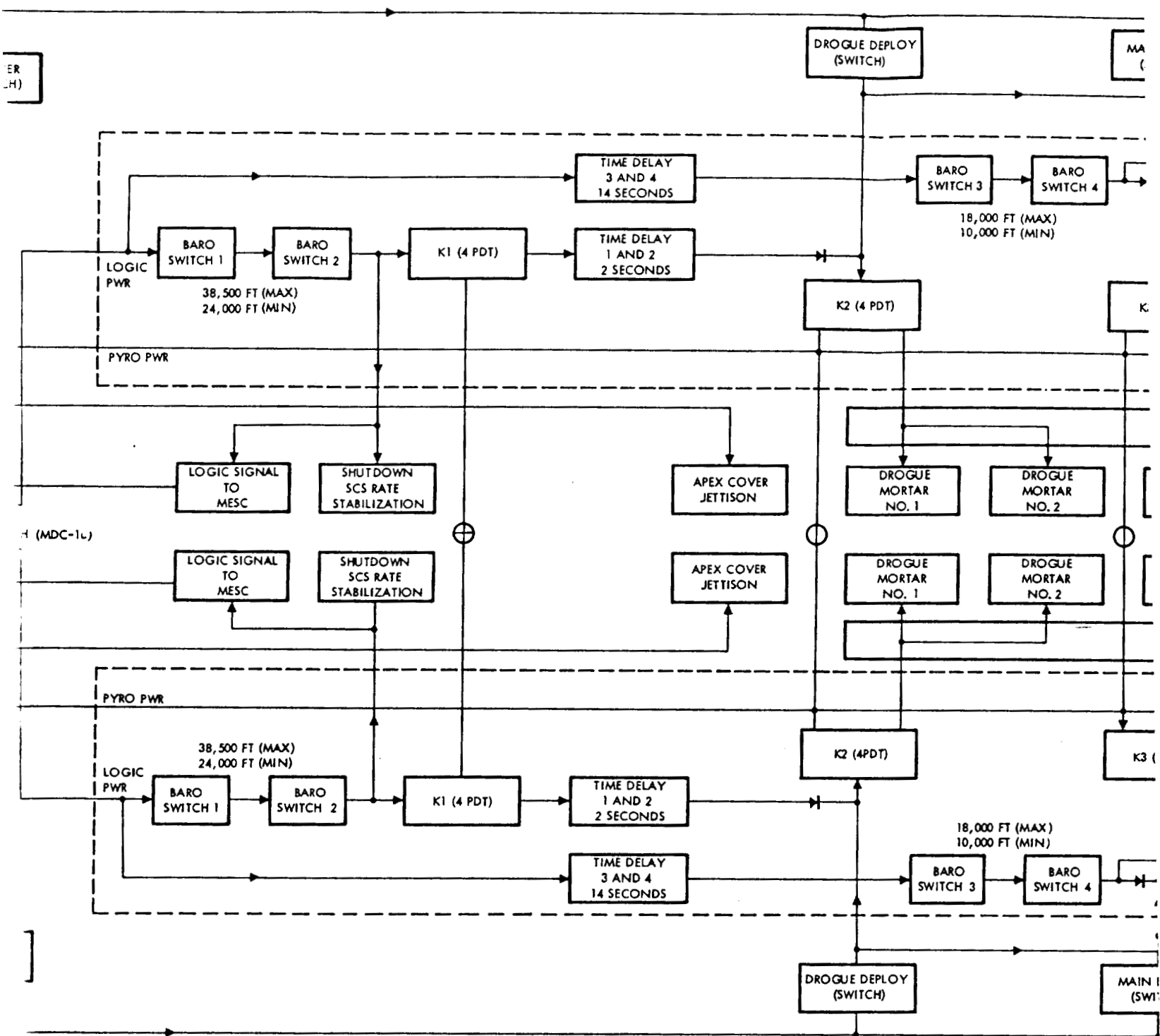
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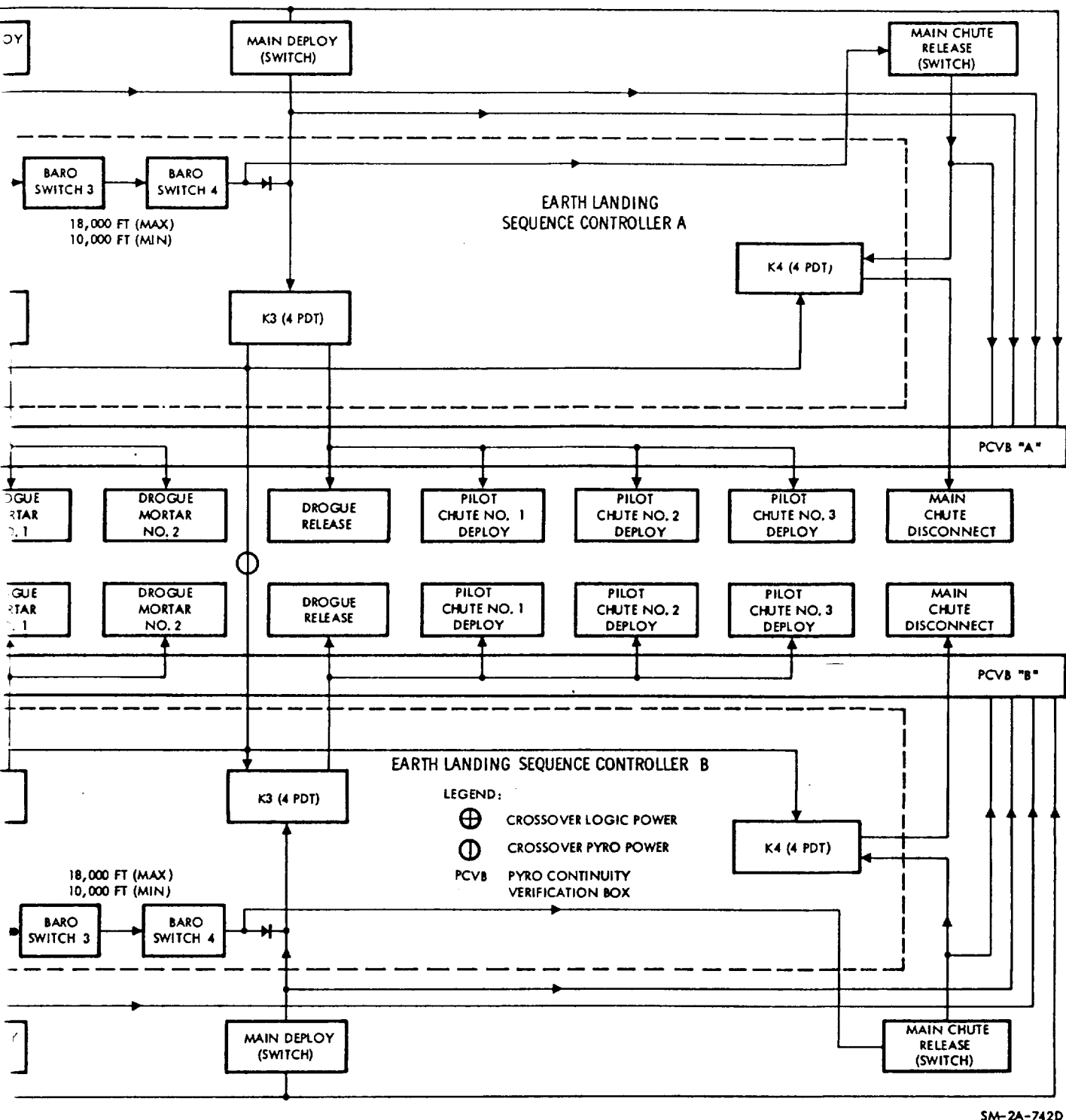


Figure 2.9-7. Earth Landing System Controller Block Diagram

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the baro switch setting. Other events are controlled by time-delay relays after the baro switches close. Refer to functional description of the ELS.

2.9.3.1.3 Command Module Reaction Control System Controllers (C/M RCSC).

The C/M RCSC (figure 2.9-8) provide automatic and manual control of events that occur in the reaction control system. Two redundant controllers are provided for dual redundancy. During an abort initiated prior to 61 seconds after lift-off, the C/M RCS oxidizer and helium are automatically dumped. When the abort signal is received, the following pyro valves are fired by initiators to pressurize and dump the RCS oxidizer:

- a. Two helium isolation valves
- b. Helium interconnect valve
- c. Oxidizer interconnect valve
- d. Two oxidizer overboard dump valves

The oxidizer overboard dump valves route the oxidizer to a blow-out plug in the aft heat shield of the C/M. Pressure buildup shears a pin which releases the blowout plug and dumps the oxidizer overboard.

The helium pressure is dumped into the aft compartment 18 seconds after abort initiation when the following pyro valves are fired by initiators:

- a. Helium interconnect valve
- b. Two oxidizer tanks bypass valves
- c. Helium overboard dump valve

The three entry batteries are automatically connected to d-c main buses A and B during an LES abort or normal C/M-S/M separation, RCS control is transferred (S/M to C/M). (See figure 2.9-9 for RCS control schematic.) The controllers inhibit automatic oxidizer dump, helium dump, and LES pitch control motor firing automatically at 61 seconds after lift-off. RCS propellant burn and purge must be manually selected.

The pyro buses are armed when the MASTER EVENT SEQ CONT - PYRO ARM switches 1 and 2 are set to the PYRO ARM position. Backup controls are provided for most of the functions performed by the RCSC.

2.9.3.1.4 Service Module Jettison Controllers (SMJC).

The SMJC (figure 2.9-10) program the operation to impart a desired motion to the service module after C/M-S/M separation. The S/M reaction control system will be controlled by the SMJC and command continuous firing of the -X jets. It is possible that the resultant -X thrusting will be offset from the S/M X-axis; therefore, the S/M RCS + roll jets are activated for a 5.5-second interval, 2 seconds after separation. This ensures that a major component of the jettison thrusting will be in a direction that was parallel to the CSM (-X) axis at

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severance. The dual controllers are powered by dual separation batteries located in the S/M. The batteries are not rechargeable during the mission.

2.9.3.1.5 C/M-S/M Separation Mechanism.

The C/M-S/M separation mechanism (figure 2.9-11) consists of electrical circuit interrupters, shear compression pads, tension ties, linear-shaped charges, and a dual-blade guillotine (umbilical severance device). Redundant systems (A and B) in the MESC provide dual redundant commands to fire dual initiators and charges to ensure sudden complete tension and umbilical severance with adequate reliability. Prior to umbilical severance, sensitive circuits in the umbilical are deadfaced by circuit interrupters. The shear compression pads are designed for interference-free separation after the tension ties are severed. A separation signal is sent to dual redundant service module jettison controllers which control the S/M after it separates from the C/M.

2.9.3.1.6 Spacecraft LEM Adapter (SLA) Separation Mechanism.

A command for CSM-SLA separation is automatically sent to the MESC when a SPS abort is manually initiated. An ADAPT SEP switch on MDC-5 may be used as a backup and for normal CSM-SLA separation during a normal mission. Separation of the adapter into four panels (figure 2.9-12) is accomplished by an explosive train. The explosive train consists of 28 charge holders, 2 initiators and shields, 8 panel thrusters, 8 initiator pressure cartridges, and an umbilical separation system. Redundant detonator assemblies fire dual lines of mild detonating fuse (MDF) installed between the adapter panels, top and bottom, and between each panel. Either line will sever the splice plates between the four panels and around both ends. Crossover boosters are used in the charge holder joints to ensure that both lines are firing simultaneously for complete reliability. The detonating lines are continuous lead sheaths surrounding an explosive core which is virgin RDX, class G. The mild detonating fuse separates the adapter panels and fires cartridges for the panel thrusters which open the four panels. Simultaneously with this operation, umbilical disconnect takes place. Four spring-loaded reels hold the panels in a 45-degree open position. The panels are stopped in the open position by eight attenuators that have honeycomb cores.

2.9.3.2 Emergency Detection System.

The EDS consists of sensors, logic circuitry and signal conditioners located in the launch vehicle, displays and controls located in the C/M, and Q-ball which is located on the forward tip of the LES tower above the canard. The displays and controls consist of L/V rates, L/V guidance, abort, and engines lights, along with an angle-of-attack

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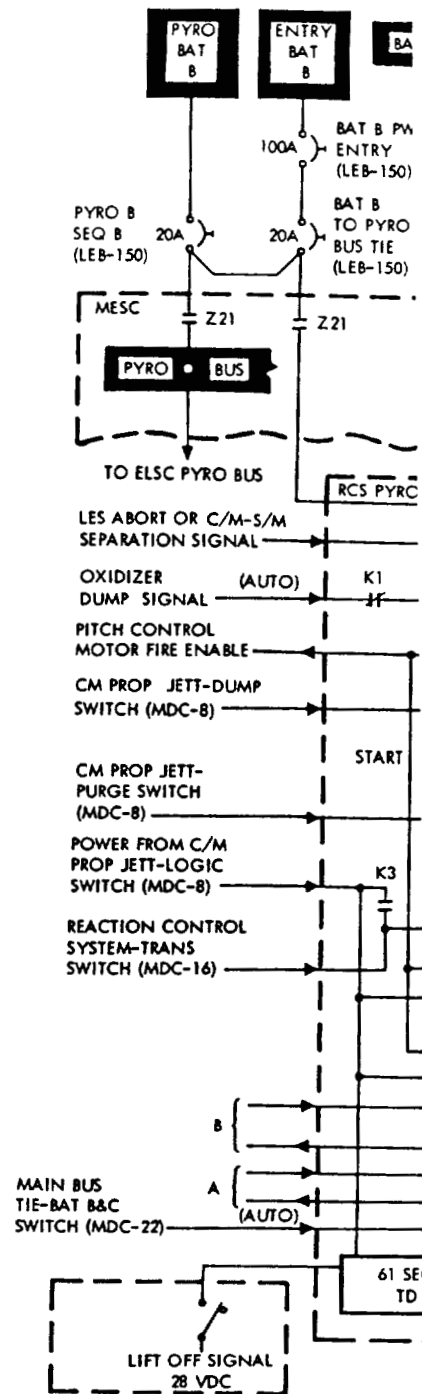
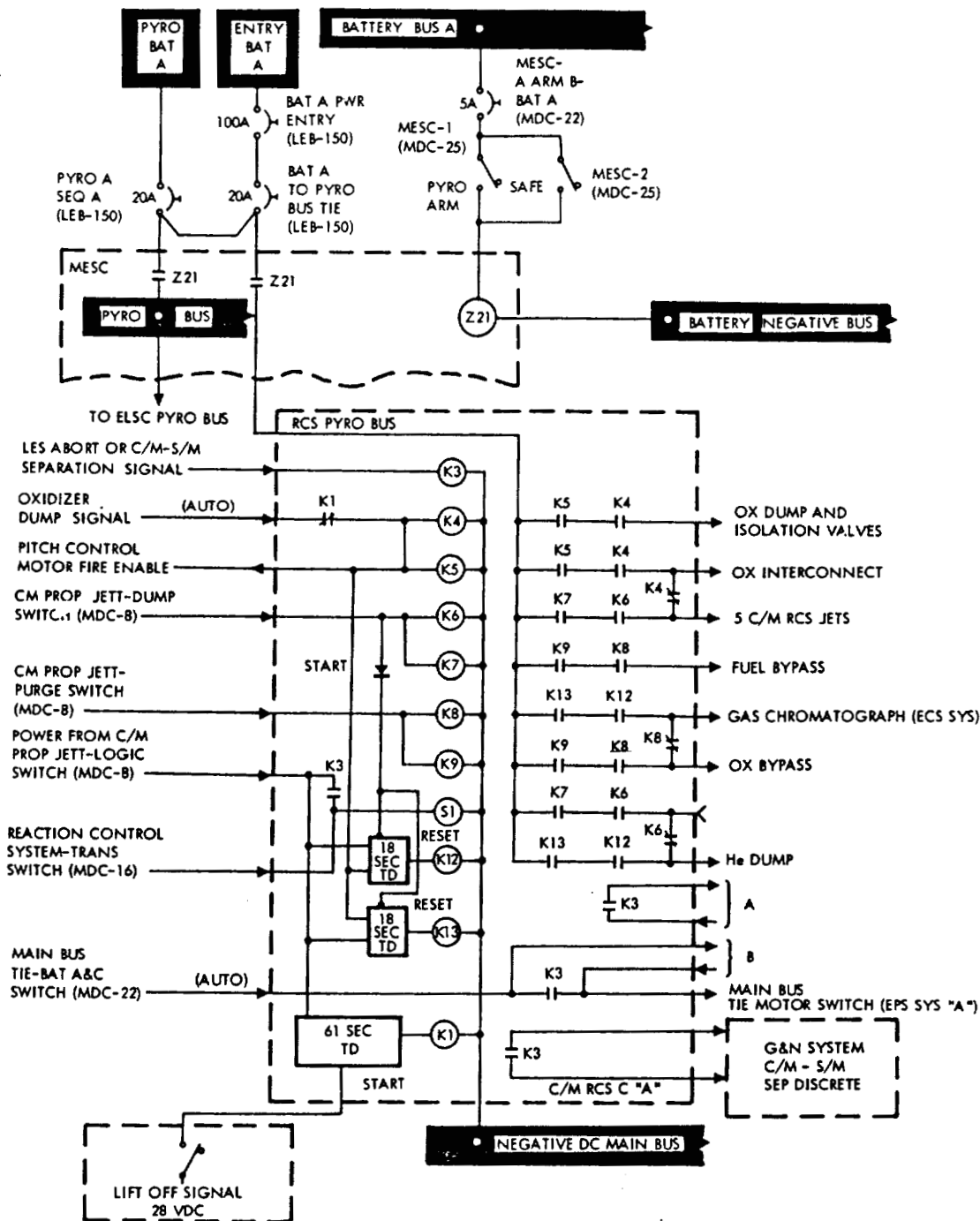


Figure 2.9-8. C/M React

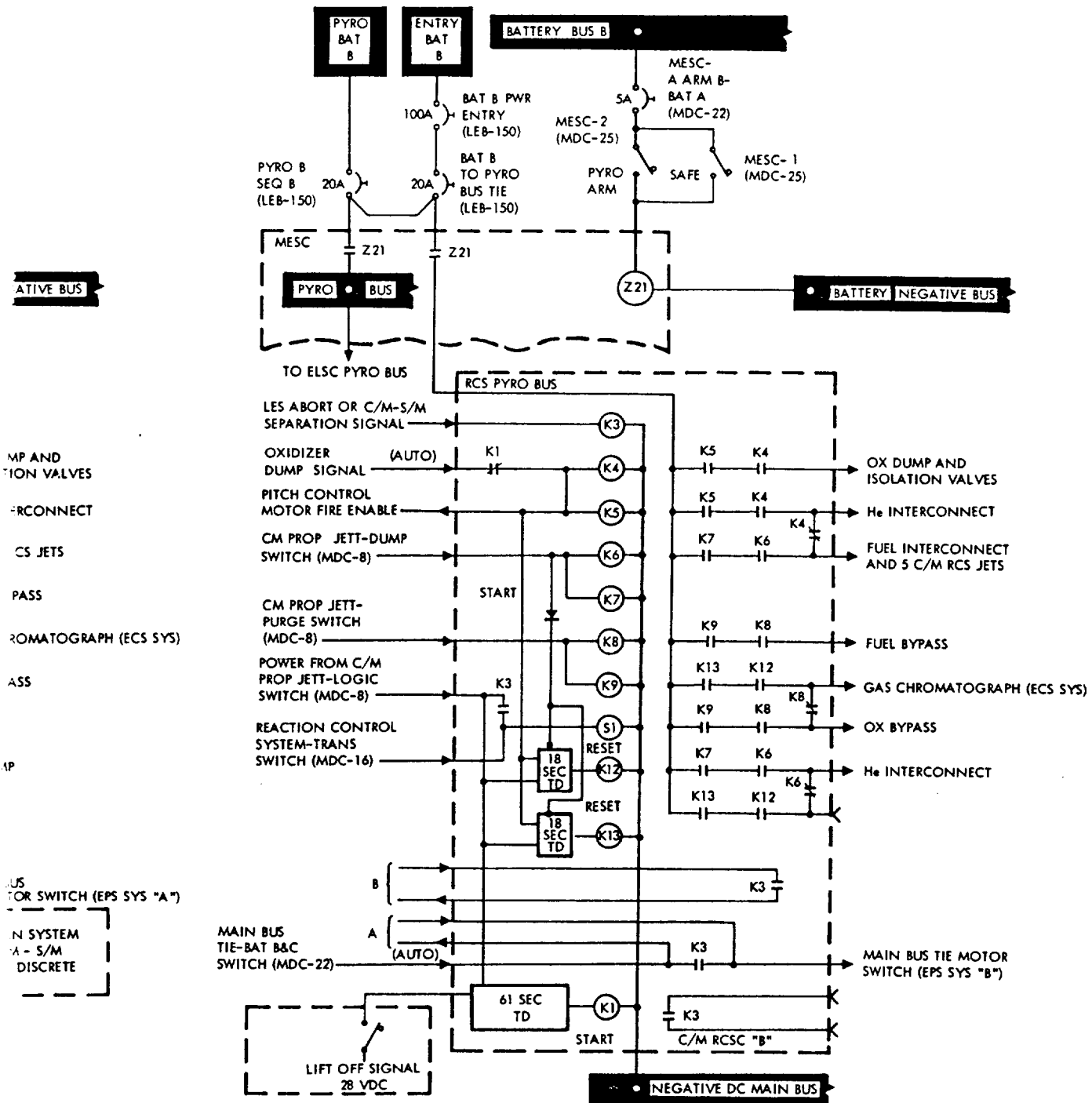
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Mission \_\_\_\_\_ Basic Date 12 Nov

FOLDOUT FRAME 1



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SM-2A-814D

Figure 2.9-8. C/M Reaction Control System Controller Schematic

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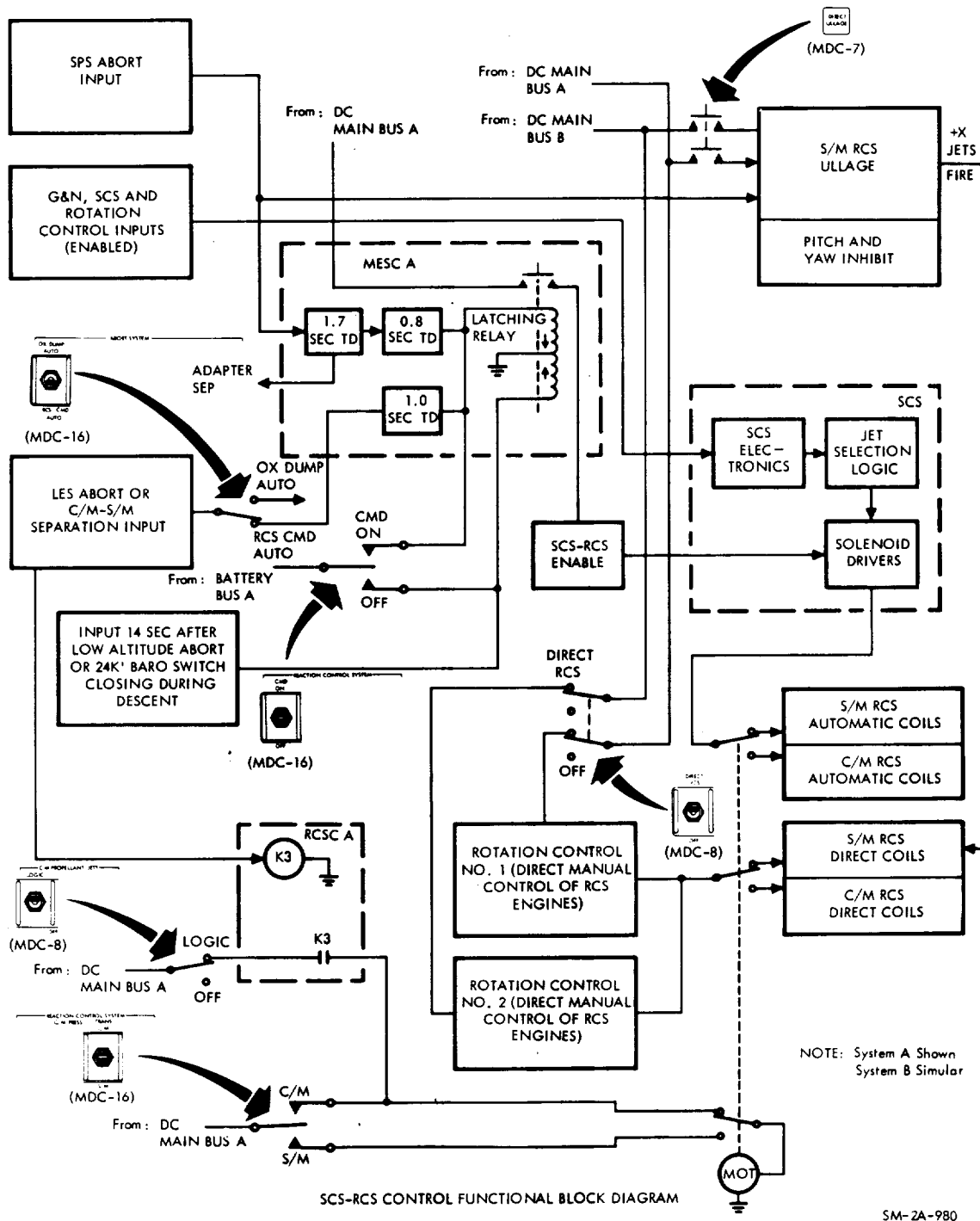


Figure 2.9-9. SCS-RCS Functional Block Diagram

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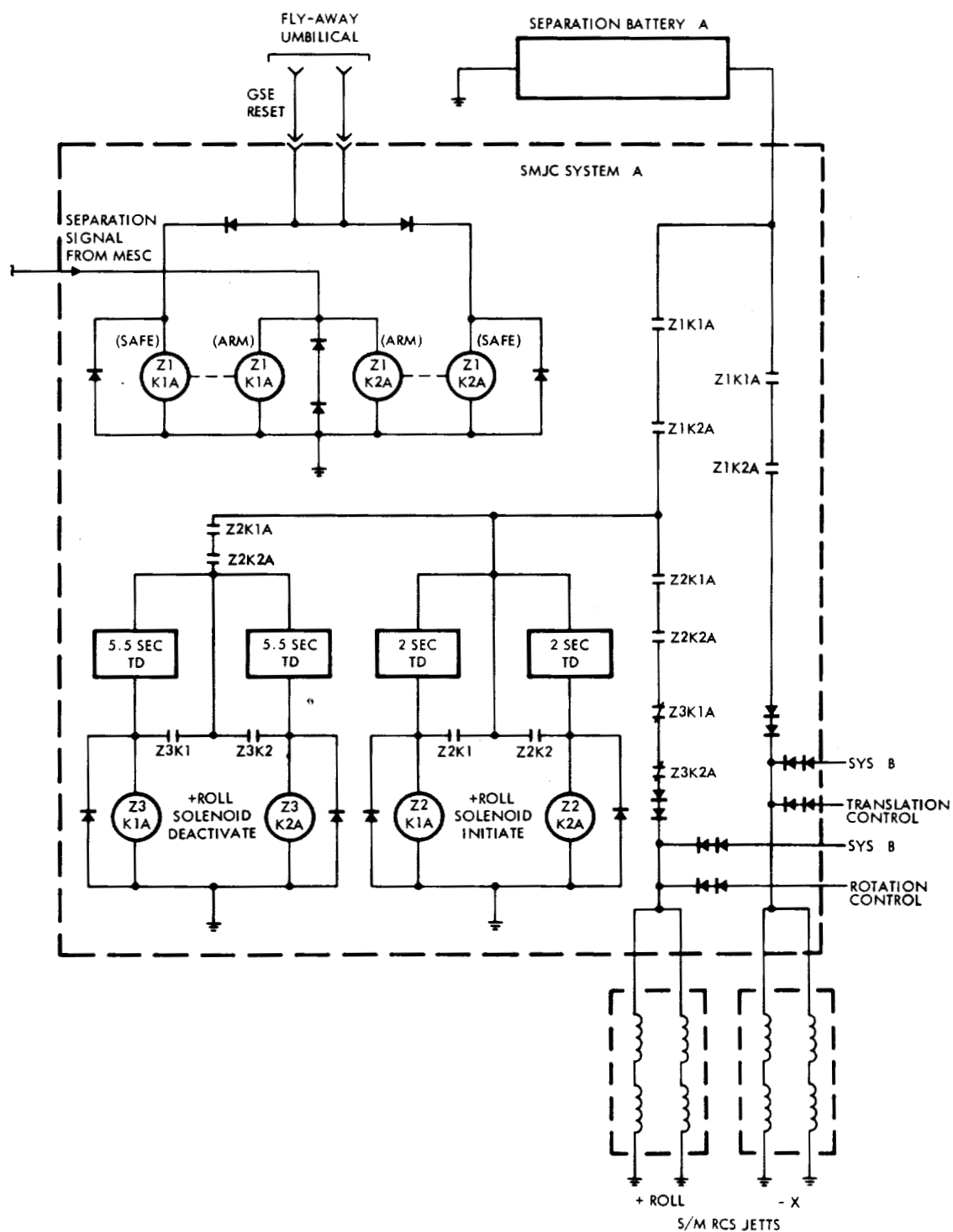
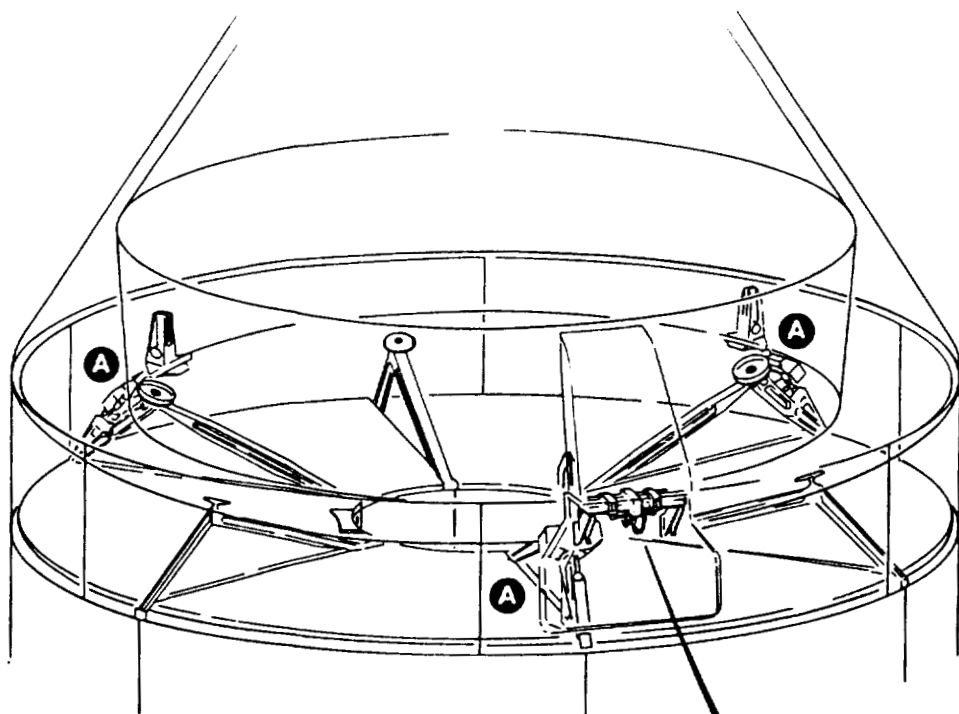


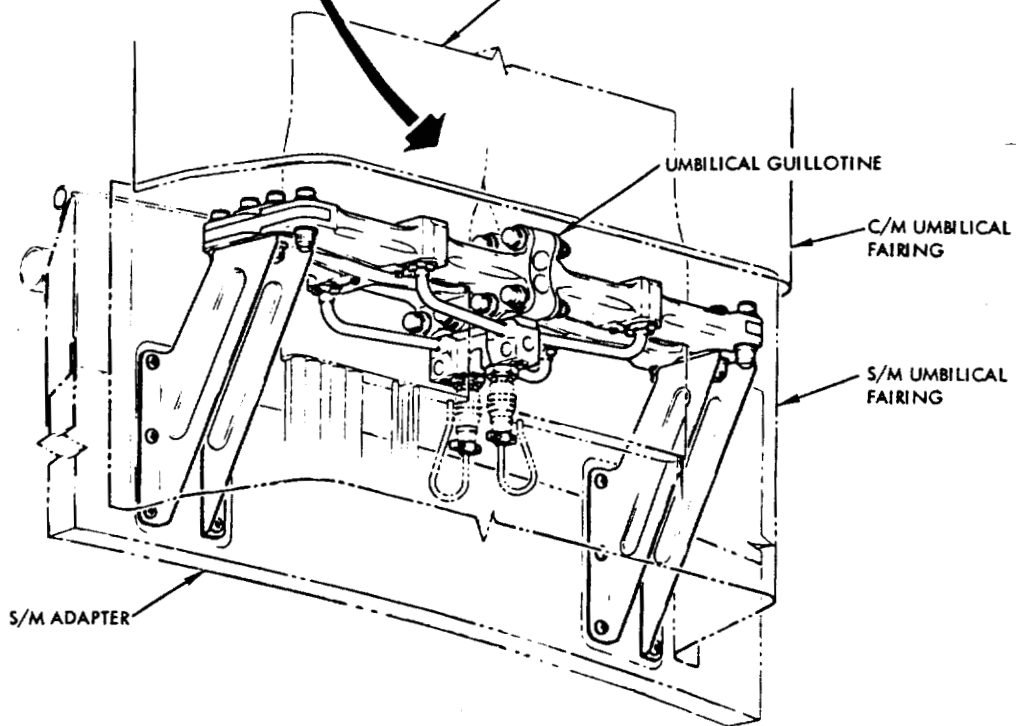
Figure 2.9-10. Service Module Jettison Controller Schematic

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COMPRESSION PADS

C/M-S/M UMBILICAL



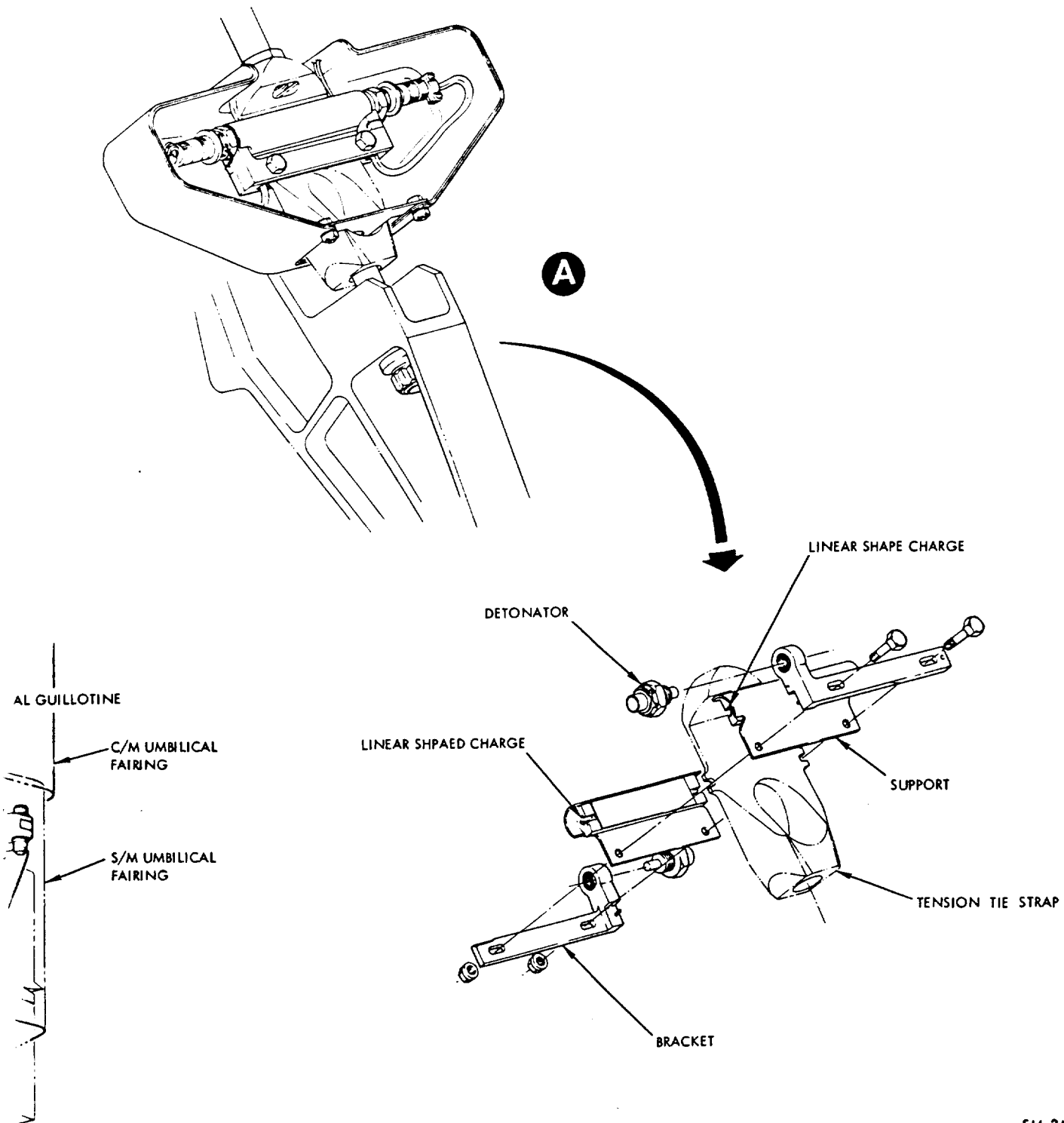
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SYSTEMS DATA



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Figure 2.9-11. C/M-S/M Separation Mechanism

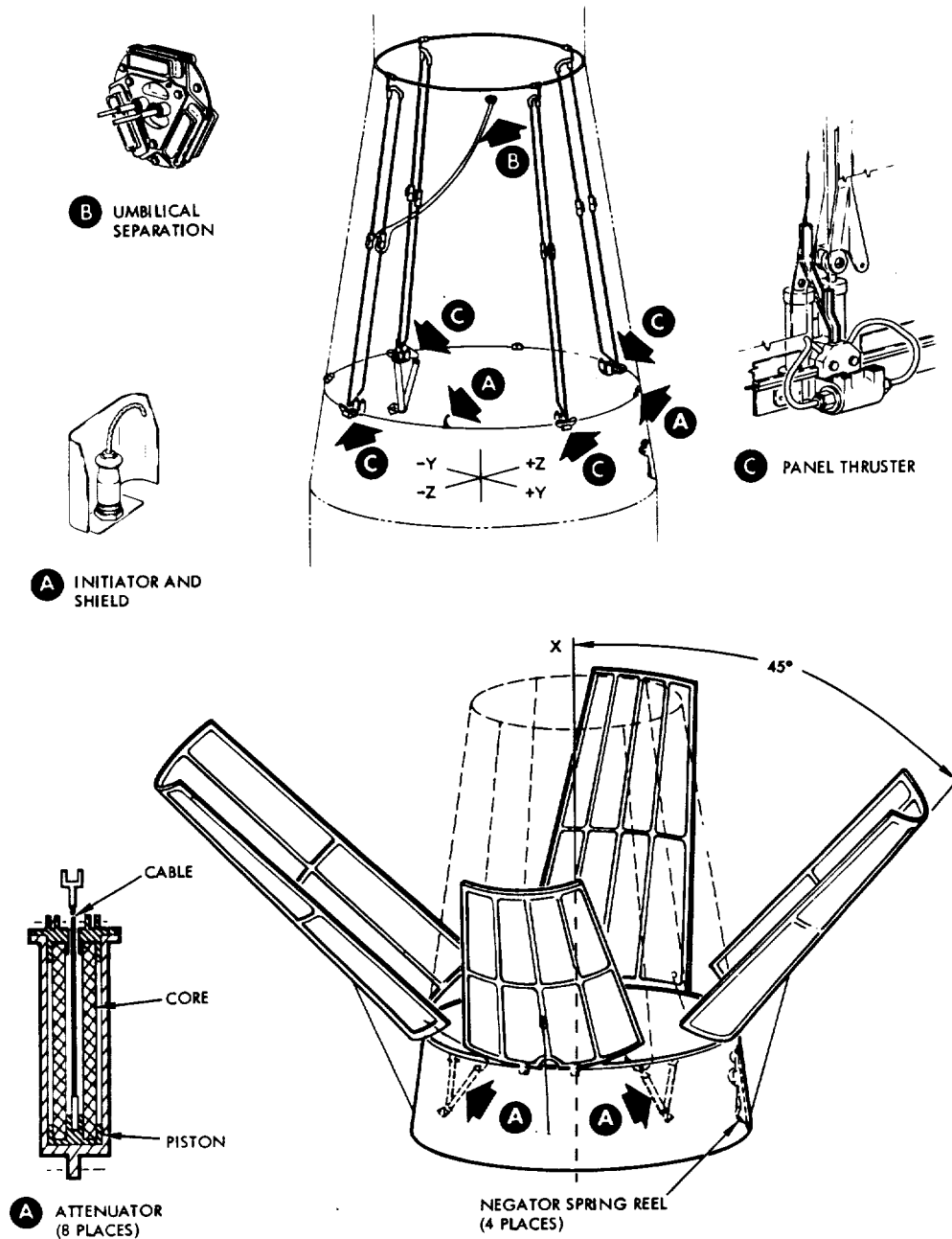
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WOLDOUT FRAME 2



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Figure 2.9-12. Adapter Separation Mechanism

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indicator and control switches. The L/V portion of the EDS and the Q-ball are powered by eight L/V batteries. The displays are powered by two entry batteries A and B.

2.9.3.3     Launch Escape System.

The LES consists of two major assemblies (figure 2.9-3) that are installed on top of the command module prior to launch. The first structure is a four-legged, welded tubular titanium tower. The tower is attached to the command module with four frangible nuts on studs. Two detonator assemblies are installed in each nut to break it when LES tower jettison is commanded. The second structure is cylindrical in shape topped by the Q-ball, and houses the launch escape, tower jettison, and pitch control motors. A canard subsystem is installed near the forward end below the Q-ball.

2.9.3.3.1    LES Motors.

Each of the three motors in the LES (figure 2.9-3) are fired by two igniter assemblies. The three motors are the launch escape motor, tower jettison motor, and pitch control motor. The pitch control motor works in conjunction with the launch escape motor during a LES abort initiated prior to 61 seconds after lift-off. The pitch control motor has a fixed zero-degree, single-exhaust nozzle and is mounted below the ballast enclosure in a horizontal position. The motor produces approximately 2500 pounds of thrust for about 0.5 second to force the nose of the LES tower in the -Z direction. Firing of the pitch control motor is inhibited 61 seconds after lift-off by a signal from the C/M RCSC. The launch escape motor has four nozzles that have a centerline cant angle of 35 degrees. The resultant thrust vector deflection is obtained by off sizing the nozzle throat diameters and producing a thrust vector in the -Z direction. Thrust output is approximately 150,000 pounds which starts dropping in approximately 4 seconds. Lateral translation of the escape vehicle is aided by the thrust vector alignment offset during an LES abort. The tower jettison motor has two nozzles in which the thrust vector alignment is offset approximately 4 degrees to produce a thrust component in the +Z direction. Thrust output is approximately 33,000 pounds.

2.9.3.3.2    Canard Subsystem.

The canard subsystem (figure 2.9-3) consists of two deployable surfaces faired into the outer skin of the LES below the Q-ball interface. Each surface is mounted on two hinges and is operated open by a pyrotechnic thruster with redundant gas cartridges. The surfaces are approximately 47 inches long, clam-shell shaped, and constructed of double-skin ribbed inconel. The canard surfaces are automatically opened during a LES abort and aerodynamic forces acting on the surfaces control a turnaround maneuver of the C/M. (Refer to Abort Procedures in section 9.)

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2.9.3.4 Earth Landing Subsystem.

The ELS consists of the parachute subsystem (figure 2.9-4), two earth landing sequence controllers (figure 2.9-7), and the apex cover jettison mechanism.

The parachute subsystem is comprised of two fist-ribbon-type nylon drogue parachutes, 13.7 feet in diameter; three ring-slot-type nylon pilot parachutes, 7.2 feet in diameter; three ring-sail-type nylon main parachutes, 83.5 feet in diameter; deployment bags; bridles; suspension lines; mortars; and the necessary hardware for attachment to the C/M. The parachute subsystem is housed in the forward compartment under the apex cover of the C/M.

The earth landing sequence controllers are located in the right equipment bay of the C/M and controls automatic operation of the ELS. Crossover circuitry between the controllers ensures correct output signals. Backup emergency switches are provided on MDC-5 for apex cover jettison and parachute deployment. The apex cover is jettisoned by four gas-operated thrusters. Two gas-type cartridges are employed for redundancy and operate two thrusters each. Either pair of thrusters will jettison the apex cover. A pilot parachute and mortar are installed in the forward end of the apex cover. The mortar is fired at exactly the same time as the apex cover thrusters to deploy the parachute. The parachute will pull the apex cover from the negative pressure area following the C/M.

2.9.4 PERFORMANCE AND DESIGN DATA.

Entry descent velocities, altitude, and time are contained in the following tabulated data. The figures are based on a command module recovery weight of 11,000 pounds and a standard day barometric pressure.

The tabulated data states the automatic events that normally occur in the ELS during descent. Under certain entry conditions, the apex cover may be manually jettisoned, and the drogue parachutes manually deployed at 45,000 feet. Refer to operational limitations and restrictions that follow the tabulated data.

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Occurrence	Altitude	Time on Parachutes	Descent Velocity
<b>TWO DROGUE PARACHUTES</b>			
24,000 feet baro switch closes	24,900 to 21,500 feet		
Apex cover jettison	24,000 feet baro switch closure + 0.4 seconds		425 ft/sec
Drogue parachutes (2) deploy	24,000 feet baro switch closure +2.0 seconds		410 ft/sec
10,000 feet baro switch closes	10,950 to 9,100 feet		
Drogue parachutes (2) release and main parachutes deploy	10,000 feet baro switch closure	45 to 46 seconds	225 ft/sec
Main parachutes open (reefed) after two drogue parachutes release			235 ft/sec
Main parachutes disreef	8400 ±500 feet	8 seconds after line stretch	110 ft/sec
<b>ONE DROGUE PARACHUTE</b>			
Drogue parachute (1) releases and main chutes deploy	10,000 feet baro switch closure	40 seconds	275 ft/sec
Main parachutes open (reefed) after one drogue parachute releases			290 ft/sec
Main parachutes disreef	8200 ±500 feet	8 seconds after line stretch	120 ft/sec
Touchdown (3 main parachutes).		5 minutes	28 ft/sec
Touchdown (2 main parachutes)		4.2 minutes	33.5 ft/sec

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2.9.4.1 Power Requirements.

The SECS requires power only during the launch and ascent phase, for CSM-SLA separation in orbit, for C/M-S/M separation during the pre-entry phase, and during the parachute descent phase. Most all events performed by the SECS occur instantaneously, and not on a continuous duty cycle. In accordance with the Mission Modular Data Book (SID 66-1177), dated 1 September 1966, there are no power requirements for the SECS.

2.9.5 OPERATIONAL LIMITATIONS AND RESTRICTIONS.

Under certain entry conditions, the spacecraft may become unstable. Because of the erratic aerodynamic damping coefficients, wind gusts, and shears, the astronaut may not be able to damp the oscillations with single RCS. If this should occur, the apex cover and drogue parachutes may be manually deployed at 45,000 feet. This will stabilize and keep the C/M in a heat shield forward descending attitude. Figure 2.9-13 portrays the drogue development design envelope. The following precautions should be observed.

- Manual initiation of apex cover jettison and drogue parachute deployment should never be accomplished above 45,000 feet during entry.
- The C/M RCS must be turned off prior to apex cover jettison.
- The LES tower and apex cover should never be manually jettisoned above the automatic mode of 24,000 feet during LES aborts.

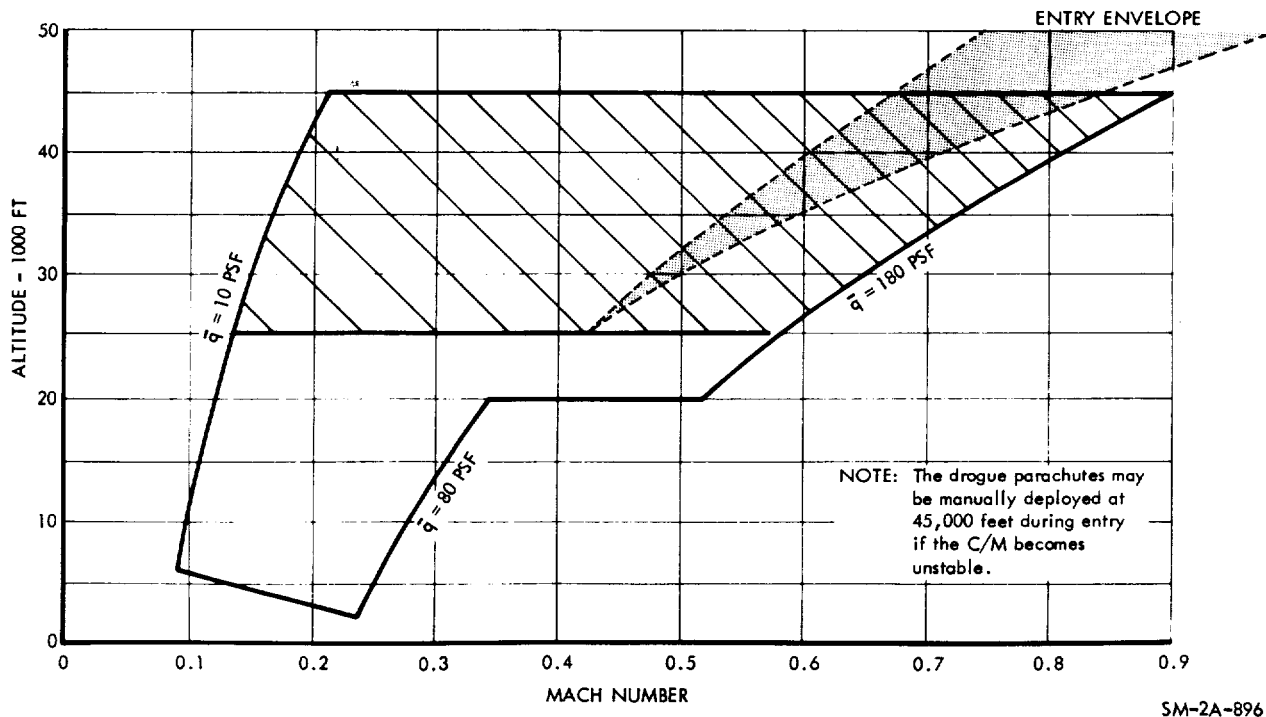


Figure 2.9-13. Drogue Parachute Deployment Design Envelope

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2.9.6 TELEMETRY MEASUREMENTS.

The following is a complete list of all sequential systems telemetry data that is monitored by flight controllers and ground support personnel. The last column contains the name and type of S/C crew display. The display utilizes the same pickoff or signal sources as telemetry, unless a separate measurement number is included in the display column.

An asterisk (\*) by the measurement number denotes information which is not available for recording or telemetry transmission during PCM low bit rate operation.

Measurement Number	Description	Sensor Range	Crew Display
CD 0136 X	EDS abort logic out B	Event	None
CD 0140 X	Direct ullage on A	Event	None
CD 0141 X	Direct ullage on B	Event	None
CD 0170 X	RCS activate signal A	Event	None
CD 0171 X	RCS activate signal B	Event	None
CD 0173 X	CM-RCS pressurize signal A	Event	None
CD 0174 X	CM-RCS pressurize signal B	Event	None
*CD 0200 V	DC voltage logic bus A	+0. +37 vdc	None
*CD 0201 V	DC voltage logic bus B	+0/+37 vdc	None
CD 0230 X	Forward heat shield jettison A	Event	None
CD 0231 X	Forward heat shield jettison B	Event	None
CD 0315 X	EDS enable A	Event	None
CD 0316 X	EDS enable B	Event	None
CD 1006 X	LES motor fire initiate A	Event	None
CD 1007 X	LES motor fire initiate B	Event	None
CE 0001 X	Drogue deploy relay close A	Event	None
CE 0002 X	Drogue deploy relay close B	Event	None
CE 0003 X	Main parachute deploy-drogue release relay A	Event	None

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Measurement Number	Description	Sensor Range	Crew Display
CE 0004 X	Main parachute deploy-drogue release relay B	Event	None
CE 0007 X	Baroswitch lock-in relay close A	Event	None
CE 0008 X	Baroswitch lock-in relay close B	Event	None
*CE 0035 P	Barometric pressure static reference	+0/+15 psia	Indicator
CE 0321 X	Main chute disconnect relay A	Event	None
CE 0322 X	Main chute disconnect relay B	Event	None
*LS 0001 V	Q-ball vector sum output	+0/+5 vdc	Indicator
BS 0016 X	Launch vehicle guidance fail A	Event	L/V GUID light
BS 0020 X	Launch vehicle rate excessive A	Event	L/V RATE light
BS 0030 X	Engine No. 1 out A	Event	ENGINES 1 light
BS 0032 X	Engine No. 2 out A	Event	ENGINES 2 light
BS 0034 X	Engine No. 3 out A	Event	ENGINES 3 light
BS 0036 X	Engine No. 4 out A	Event	ENGINES 4 light
BS 0038 X	Engine No. 5 out A	Event	ENGINES 5 light
BS 0040 X	Engine No. 6 out A	Event	ENGINES 6 light
BS 0042 X	Engine No. 7 out A	Event	ENGINES 7 light
BS 0044 X	Engine No. 8 out A	Event	ENGINES 8 light
BS 0061 X	Lift-off signal B	Event	LIFT OFF light

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Measurement Number	Description	Sensor Range	Crew Display
CS 0080 X	EDS abort request A	Event	ABORT light
*LS 0090 X	Tower physical separation monitor A	Event	None
*LS 0091 X	Tower physical separation monitor B	Event	None
CS 0100 X	CM-SM physical separation monitor A	Event	None
CS 0101 X	CM-SM physical separation monitor B	Event	None
SS 0120 X	SM/adapter physical separation monitor A	Event	None
SS 0121 X	SM/adapter physical separation monitor B	Event	None

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SECTION 2

SUBSECTION 2.10

CAUTION AND WARNING SYSTEM (C&WS)

2.10.1 INTRODUCTION.

The C&WS monitors critical parameters of most S/C systems in the C/M and S/M. When a malfunction or out-of-tolerance condition occurs in any of these systems, the crew is immediately alerted in order that corrective action may be taken.

2.10.2 FUNCTIONAL DESCRIPTION.

Upon receipt of malfunction or out-of-tolerance signals, the C&WS simultaneously identifies the abnormal condition and alerts the crew to its existence. Each signal will activate an appropriate systems status indicator and a master alarm circuit. The master alarm circuit visually and aurally attracts the crew's attention by alarm indicators on the MDC and an alarm tone in the headsets. Crew acknowledgement of an abnormal condition consists of resetting the master alarm circuit, but retaining the particular systems status malfunction indication. The capability exists for the crew to select several modes of observing systems status and master alarm indicators, and of monitoring C/M or S/M systems.

2.10.3 MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

The C&WS consists of one major component, the detection unit. It is located behind MDC-13 and, therefore, is neither visible nor accessible to the crew during the mission. The balance of the system is made up of visual indicators, aural alerting and associated circuits, and those switches required to control the various system functions. Visual indicators include the five upper-most electromechanical event devices on MDC-18, as well as all systems status and master alarm lights.

The detection unit circuits consist of comparators, logic, level detectors, lamp drivers, and a master alarm and tone generator. Also incorporated are two redundant power supplies that furnish regulated +12 and -12 d-c voltages for the electronics. Inputs to the detection unit consist of both analog and event-type signals.

The analog signals, totaling 51 inputs, are in the 0- to 5-volt d-c range. Alarm limits for these signals trigger voltage comparators, which, in turn, activate logic and lamp-driver circuits. This causes activation of the master alarm circuit and tone generator, illumination of application systems status lights on MDC-10 and -11, and/or activation of applicable electromechanical event indicators on MDC-18. A total of 25 event inputs are fed to the C&WS detection unit. These signals originate from solid state and mechanical switch closures in malfunction sensing devices. Of this number, 19 signals will directly illuminate applicable system status lights, and through logic circuitry, activate the master alarm circuit (and tone generator). Two other event signals directly illuminate the system

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status lights, but require level detectors to activate the master alarm circuit. Each of the four remaining event signals is set to an OR gate, which is also fed by two analog signals. The resulting output will activate lamp drivers and the master alarm circuit. One other event signal, originating within the detection unit directly, illuminates the CAUT/WARN FAIL light, but activates only the MASTER ALARM lights of the MASTER ALARM circuit.

The master alarm circuit alerts crewmembers whenever abnormal conditions are detected. This is accomplished visually by the illumination of remote MASTER ALARM switch-lights on MDC-3 and -18, and the MASTER ALARM light on LEB-103. An audio alarm tone, sent to the three headsets, aurally alerts the crew, regardless of whether the telecom system is activated. The output signal of the tone generator is a square wave that is alternately 750 cps and 2000 cps, changing at a frequency of 2.5 cps. Although the tone is audible above the conversation level, it does not render normal conversation indistinct or garbled. When the crew has noted the abnormal condition, the three alarm lights and the tone generator are deactivated and reset by pressing either MASTER ALARM switch-light, both of which incorporate a push-switch. This action leaves the systems status lights illuminated, and resets the master alarm circuit for alerting the crew to the next abnormal condition. The individual system status lights will remain illuminated until the malfunction or out-of-tolerance condition is corrected.

The C&WS power supplies include sensing and switching circuitry that assure unit self-protection should high-input current, or high- or low-output voltage occur. Any of these conditions will cause the illumination of the master alarm lights and the CAUT-WARN FAIL systems status light. The tone generator, however, will not be activated due to requiring the 12-volt output from the malfunctioned power supply for its operation. The crew must then manually select the redundant power supply to return the C&WS to operation. In so doing, the CAUT/WARN FAIL status light is extinguished, but the master alarm circuit is activated, thus requiring it to be reset.

Incorporated into the C&WS is the capability to test the lamps of systems status and master alarm lights. Position 1 of the LAMP TEST switch (MDC-23) controls the illumination of status lights on MDC-10 and the MASTER ALARM switch-lights on MDC-3 and MDC-18. Position 2 tests only the status lights on MDC-11. The remaining MASTER ALARM light is on LEB-103, and is tested along with the nine G&N condition lights on that panel by pressing the CHECK CONDITION LAMPS push-switch on LEB-105. Although these nine lights are not part of the C&WS, all but three of them (PGNS, ZERO ENCODER, and IMU DISPLAY) are duplicated on MDC-10.

Switches on the MDC enable the crew to select C&WS operational modes. The position of the MODE switch (MDC-11) establishes the S/C systems to be monitored. Before separation and entry, systems in both the C/M and S/M are monitored for malfunction or out-of-tolerance conditions. After CSM separation, however, only those systems in the C/M are monitored. Repositioning the switch also prevents S/M systems status lights and event indicators from remaining activated after separation.

The C/W switch (MDC-13) permits three modes of status and alarm light illumination. For most of the mission the switch is set to the NORMAL position to give normal C&WS light operation; that is, upon receipt of abnormal condition signals, all systems status lights and master alarm

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lights are capable of illumination. During the ascent phase the switch is set to the BOOST position, so that although all other C&WS lights operate normally, the MASTER ALARM switch-light on MDC-3 will not illuminate. This prevents possible confusion on MDC-3 between the red MASTER ALARM light and the adjacent red ABORT light. The ACK switch position is selected when the crew desires to adapt their eyes to orbital darkness, or if a continuously illuminated systems status light is undesirable. While in this mode, incoming signals will activate only the master alarm lights and the tone generator. To determine the abnormal condition, the crew must press either MASTER ALARM switch-light. This illuminates the applicable systems status light, and deactivates and resets the master alarm circuit. The systems status light will remain illuminated only as long as the switch-light is pressed. However, it may be recalled as long as the abnormal condition exists by again pressing either switch-light.

2.10.3.1 Electrical Power Distribution.

The C&WS only receives power from 28-volt d-c sources. (See figure 2.10-1.) Before CSM separation, the power source is from the fuel cells in the S/M, and following separation, from batteries located in the C/M.

2.10.4 PERFORMANCE AND DESIGN DATA.

2.10.4.1 C&WS Power Consumption Data.

Total power consumed by the C&WS amounts to 7.5 watts, which is the maximum quiescent power for detection unit operation. Very small amounts of power are also required to illuminate several lamps whenever the C&WS is activated by malfunction input signals. These small amounts, however, are not considered in the overall C&WS power requirements.

2.10.5 OPERATIONAL LIMITATIONS AND RESTRICTIONS.

2.10.5.1 C&WS General Data.

With the C/W switch in the BOOST position during ascent, the MASTER ALARM switch-light on MDC-3 will not illuminate should a malfunction occur. The master alarm circuit reset capability of the light is also disabled during this time. This requires the MASTER ALARM switch-light on MDC-18 to be used exclusively for monitoring and resetting functions.

Several peculiarities should be noted in regard to the CAUT/WARN-POWER switch. Whenever this switch is moved from, or through, the OFF position to either power supply position, the master alarm circuit is activated, which then requires it be reset. Also, switching from one power supply to another (when there is not power supply failure) will cause the CAUT/WARN FAIL status light to illuminate at the OFF position, and then be extinguished when the other power supply position is reached.

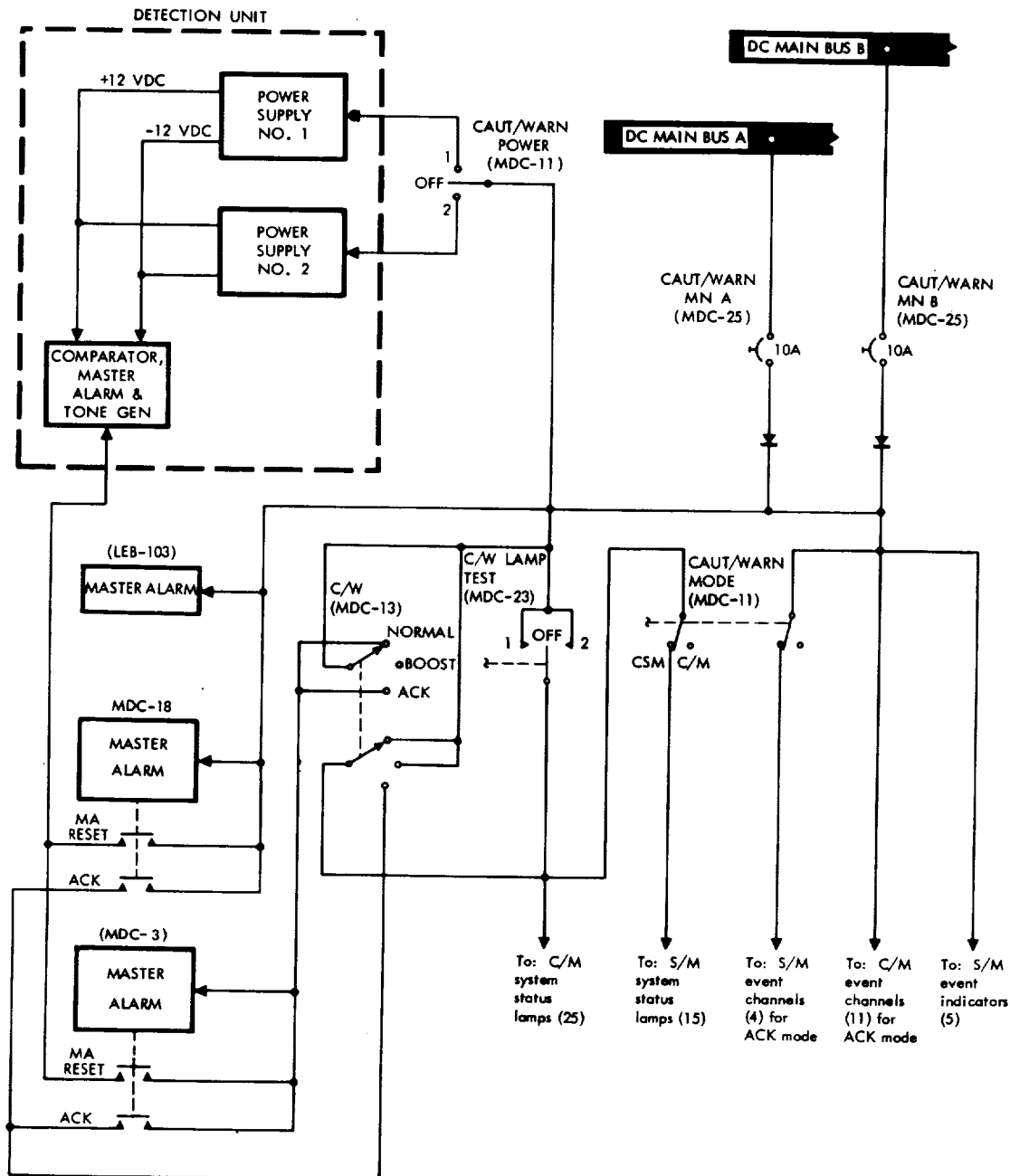
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Figure 2.10-1. C&WS Power Distribution Diagram

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Should the redundant power supply also fail, the C&WS is degraded to the following extent. Rendered inoperative is the complete master alarm circuit, as well as those status lights that illuminate as the result of analog-type input signals. This leaves only those status lights operative that require event-type input signals. Included are the following S/M and C/M lights: CDU FAIL, G&N ACCEL FAIL, IMU FAIL, G&N ERROR, IMU TEMP, GMBL LOCK, AGAP TEMP, SPS ROUGH ECO, H<sub>2</sub>P ACCUM FAIL, PITCH GMBL DR FAIL, YAW GMBL DR FAIL, SPS PU SNSR FAIL, O<sub>2</sub> FLOW HI, F/C BUS DISCONNECT, AC 1 BUS FAIL, AC BUS 1 OVERLOAD, AC 2 BUS FAIL, AC BUS 2 OVERLOAD, MN BUS A UNDERVOLT, MN BUS B UNDERVOLT, and CAUT/WARN FAIL.

The CAUT/WARN-MODE switch must be in the CSM position in order to conduct a lamp test of those status lights associated with S/M systems. The status lights of C/M systems may be tested with the MODE switch in either position. Circuit design also permits a complete lamp test to be conducted with the C/W switch in the ACK position.

Normally, each abnormal condition signal will activate the C&WS master alarm circuit and tone generator, and illuminate an applicable systems status light. The one exception to this concept is when the C&WS power supply fails. The visual indicators will function, but not the tone generator portion of the master alarm circuit. This is due to the tone generator requiring the +12 and -12 d-c voltage output of the failed power supply for its operation.

The MASTER ALARM light on LEB-103 is part of the master alarm circuit of the C&WS. As such, it is illuminated whenever the master alarm circuit is activated by an incoming abnormal condition signal. A lamp check of this light, however, is not accomplished by the C&WS. Instead, the light is checked by pressing the CHECK CONDITION LAMPS push-switch on LEB-105. The primary function of this switch is to check the lamps of the nine G&N condition lights on LEB-103, none of which are part of the C&WS.

2.10.5.2 System Status Light Data.

The following list provides the lamp trigger values and associated information for all system status lights on MDC-10 and -11.

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Status Light	Lamp Trigger Value	TLM Code No.	Other Indication	S/C Mode	Remarks
CDU FAIL	1. Loss (-50%) 25.6KC supply 2. Loss (-50%) motor excitation 3. ICDU error >1.2 mr for 5 seconds 4. MCDU error >1.2 mr for 5 seconds 5. OCDU error >1.2 mr for 5 seconds	CG5002X	PGNS light illuminated (LEB-103).	C/M	Light enabled in fine align mode only.
IMU FAIL	1. Loss (-50%) 3200 cps 2. Loss (-50%) 800 cps wheel power 3. IG servo air >2.9 mr for 2 seconds 4. MG servo air >2.9 mr for 2 seconds 5. OG servo air >2.9 mr for 2 seconds	CG5001X	PGNS light illuminated (LEB-103).	C/M	Inhibited (by AGC program) in coarse align mode.
IMU TEMP	1. IRIG temp <132°F 2. IRIG temp >138°F 3. PIPA temp <132°F 4. PIPA temp >138°F	CG5006X	None	C/M	IRIG temp (135°F) is internal and not end cap temp.
AGAP TEMP	1. Any BMAG <160°F 2. Any BMAG >171°F	CH2030V	None	C/M	
G&N ACCEL FAIL	1. X PIPA error >27 mr for 5 seconds 2. Y PIPA error >27 mr for 5 seconds 3. Z PIPA error >27 mr for 5 seconds	CG5000X	PGNS light illuminated (LEB-103).	C/M	
G&N ERROR	1. Down TLM word rate too high or low 2. Up TLM bit rate too high 3. Up-link data in error	CG5005X	DSKY-TM FAIL (LEB-106) and PGNS lights (LEB-103) illuminated.	C/M	
GMBL LOCK	MG angle >±60°	CG5003X	FDAI attitude ball red zone under new axis indicator.	C/M	
H <sub>2</sub> PRESS	1. Tank 1 <220 psia 2. Tank 1 >270 psia 3. Tank 2 <220 psia 4. Tank 2 >270 psia	SF0039P SF0040P	TANK PRESSURE-H <sub>2</sub> -1 indicator TANK PRESSURE-H <sub>2</sub> -1 indicator	S/M	
C/M RCS A	1. Fuel tk He press <265 psia 2. Fuel tk He press >325 psia 3. Ox tk He press <265 psia 4. Ox tk He press >325 psia	CR0005P CR0011P	C/M RCS PRESS-F indicator C/M RCS PRESS-OX indicator	C/M	Light functional only when CAUT/WARN-MODE switch in C/W.
C/M RCS B	1. Fuel tk He press <265 psia 2. Fuel tk He press >325 psia 3. Ox tk He press <265 psia 4. Ox tk He press >325 psia	CR0006P CR0012P	C/M RCS PRESS-F indicator C/M RCS PRESS-OX indicator	C/M	Light functional only when CAUT/WARN-MODE switch in C/M.
AGC PWR FAIL	1. Loss of +28 vdc supply 2. Loss of +13 vdc supply 3. Loss of -3 vdc supply	CG5030X	PGNS light illuminated (LEB-103).	C/M	

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Status Light	Lamp Trigger Value	TLM Code No.	Other Indication	S/C Mode	Remarks
O <sub>2</sub> PRESS	1. Tank 1 <800 psia 2. Tank 1 >950 psia 3. Tank 2 <800 psia 4. Tank 2 >950 psia	SF0037P SF0038P	TANK PRESSURE-O <sub>2</sub> -1 indicator TANK PRESSURE-O <sub>2</sub> -2 indicator	S/M	
S/M RCS A	1. Pkg temp <63°F 2. Pkg temp >175°F 3. Reg He press <155 psia 4. Reg He press >215 psia	SR5065T SR5729P	S/M RCS TEMP-PKG indicator S/M RCS PRESS-MANF indicator	S/M	
S/M RCS B	1. Pkg temp <63°F 2. Pkg temp >175°F 3. Reg He press <155 psia 4. Reg He press >215 psia	SR5066T SR5776P	S/M RCS TEMP-PKG indicator S/M RCS PRESS-MANF indicator	S/M	
S/M RCS C	1. Pkg temp <63°F 2. Pkg temp >175°F 3. Reg He press <155 psia 4. Reg He press >215 psia	SR5067T SR5817P	S/M RCS TEMP-PKG indicator S/M RCS PRESS-MANF indicator	S/M	
S/M RCS D	1. Pkg temp <63°F 2. Pkg temp >175°F 3. Reg He press <155 psia 4. Reg He press >215 psia	SR5068T SR5830P	S/M RCS TEMP-PKG indicator S/M RCS PRESS-MANF indicator	S/M	
SPS ROUGH ECO	1. 180G's for 70 m seconds 2. 360G's for 30 m seconds	None	Engine cuts off.	S/M	G-levels are peak-to-peak.
H <sub>2</sub> O ACCUM FAIL	Three O <sub>2</sub> bubbles (min) in outlet water line	None	None	C/M	
F/C BUS DISCONNECT	1. Fwd current at 75 amps for 15 min, or at 112 amps for 25 to 300 seconds 2. Reverse current at 4 amps for 10 sec, or 20 amps for 1 sec.	SC2120X SC2121X SC2122X SC2125X SC2126X SC2127X	MN BUS A event indicator (3) MN BUS B event indicator (3)	S/M	
F/C 1	1. H <sub>2</sub> flow <0.018 lb/hr 2. H <sub>2</sub> flow >0.16 lb/hr 3. O <sub>2</sub> flow <0.14 lb/hr 4. O <sub>2</sub> flow >1.27 lb/hr 5. At pH factor of 9 6. Skin temp <360°F 7. Skin temp >500°F 8. Cond exh <155°F 9. Cond exh >175°F 10. Rad out temperature below -30°F 11. H <sub>2</sub> reg press >75 psia 12. O <sub>2</sub> reg press >75 psia 13. N <sub>2</sub> reg press >70 psia	SC2139R SC2142R SC2160X SC2084T SC2081T SC2087T SC2069P SC2066P SC2060P	FUEL CELL-FLOW- H <sub>2</sub> indicator FUEL CELL-FLOW- O <sub>2</sub> indicator pH HI event ind MODULE TEMP-SKIN indicator MODULE TEMP-COND EXH indicator F/C RAD TEMP LOW event indicator REG OUT PRESS HI -H <sub>2</sub> event ind REG OUT PRESS HI -O <sub>2</sub> event ind REG OUT PRESS HI -N <sub>2</sub> event ind	S/M	Event indicators pH, HI, F/C RAD TEMP LO, H <sub>2</sub> PRESS, O <sub>2</sub> PRESS, and N <sub>2</sub> PRESS are activated at lamp trigger values.
INV 1 TEMP HI	At 241°F	CC0175T	None	C/M	
GLYCOL TEMP LOW	At -30°F	CF0020T	GLY EVAP-OUTLET TEMP indicator	C/M	

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Status Light	Lamp Trigger Value	TLM Code No.	Other Indication	S/C Mode	Remarks
SPS PRESS	1. Fuel tk He press <160 psia 2. Fuel tk He press >200 psia 3. Ox tk He press <160 psia 4. Ox tk He press >200 psia	SP0006P SP0003P	PRESSURE-FUEL indicator PRESSURE-OX indicator	S/M	
F/C 2	1. H <sub>2</sub> flow <0.018 lb/hr 2. H <sub>2</sub> flow >0.16 lb/hr 3. O <sub>2</sub> flow <0.14 lb/hr 4. O <sub>2</sub> flow >1.27 lb/hr 5. At pH factor of 9 6. Skin temp <360°F 7. Skin temp >500°F 8. Cond exh <155°F 9. Cond exh >175°F 10. Rad out temp below -30°F 11. H <sub>2</sub> reg press >75 psia 12. O <sub>2</sub> reg press >75 psia 13. N <sub>2</sub> reg press >70 psia	SC2140R SC2143R SC2161X SC2085T SC2082T SC2088T SC2070P SC2067P SC2061P	FUEL-CELL-FLOW-H <sub>2</sub> indicator FUEL CELL-FLOW-O <sub>2</sub> indicator pH HI event ind MODULE TEMP-SKIN indicator MODULE TEMP-COND EXH indicator F/C RAD TEMP LOW event indicator REG OUT PRESS HI-H <sub>2</sub> event indicator REG OUT PRESS HI-O <sub>2</sub> event indicator REG OUT PRESS HI-N <sub>2</sub> event indicator	S/M	Event indicator pH HI, F/C RAD TEMP LO, H <sub>2</sub> PRESS, O <sub>2</sub> PRESS, and N <sub>2</sub> PRESS are activated at lamp trigger values.
INV 2 TEMP HI	At 240°F	CC0176T	None	C/M	
PITCH GMBL DR FAIL	1. Under 6 amps 2. Over 40 amps	SP1000X	None	S/M	Overcurrent conditions dependent upon time and temp.
SPS WALL TEMP HI	At 378°F	SP0020T	None	S/M	
F/C 3	1. H <sub>2</sub> flow <0.018 lb/hr 2. H <sub>2</sub> flow >0.16 lb/hr 3. O <sub>2</sub> flow <0.14 lb/hr 4. O <sub>2</sub> flow >1.27 lb/hr 5. At pH factor of 9 6. Skin temp <360°F 7. Skin temp >500°F 8. Cond exh <155°F 9. Cond exh >175°F 10. Rad out temp below -30°F 11. H <sub>2</sub> reg press >75 psia 12. O <sub>2</sub> reg press >75 psia 13. N <sub>2</sub> reg press >70 psia	SC2141R SC2144R SC2162X SC2086T SC2083T SC2089T SC2071P SC2068P SC2062P	FUEL CELL-FLOW-H <sub>2</sub> indicator FUEL CELL-FLOW-O <sub>2</sub> indicator pH HI event ind MODULE TEMP-SKIN indicator MODULE TEMP-COND EXH indicator F/C RAD TEMP LOW event indicator REG OUT PRESS HI-H <sub>2</sub> event indicator REG OUT PRESS HI-O <sub>2</sub> event indicator REG OUT PRESS HI-N <sub>2</sub> event indicator	S/M	Event indicators pH HI, F/C RAD TEMP LO, H <sub>2</sub> PRESS, O <sub>2</sub> PRESS, and N <sub>2</sub> PRESS are activated at lamp trigger values.
INV 3 TEMP HI	At 241°F	CC0177T	None	C/M	
YAW GMBL DR FAIL	1. Under 6 amps 2. Over 40 amps	SP1001X	None	S/M	Overcurrent condition dependent upon time and temp.
SPS PU SNSR FAIL	1. F/OX ratio unbalance over 300 lbs, or 90% of critical unbalance. 2. Primary and aux systems 1 to 3% discrepancy.	None	UNBALANCE indicator (for over 300 lbs only)	S/M	Light functional only during SPS firing.

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Status Light	Lamp Trigger Value	TLM Code No.	Other Indication	S/C Mode	Remarks
MN BUS A UNDERVOLT	At 26.25±0.1 vdc	CG0206V	DC VOLTS meter	C/M	
MN BUS B UNDERVOLT	At 26.25±0.1 vdc	CG0207V	DC VOLTS meter	C/M	
CO <sub>2</sub> PP HI	At 7.6 mm Hg	CF0005P	PART PRESS CO <sub>2</sub> indicator	C/M	
AC BUS 1 FAIL	1. At 95±3 vdc 2. At 130±2 vdc	CG0200V CG0201V CG0202V	AC VOLTS meter	C/M	
AC BUS 2 FAIL	1. At 95±3 vdc 2. At 130±2 vdc	CC0203V CC0204V CC0205V	AC VOLTS meter	C/M	
CAUT/WARN FAIL	1. At +11.7 vdc or -11.7 vdc 2. At +13.9 vdc or -13.9 vdc	None	MASTER ALARM lights (3)	C/M	Alarm tone inoperative.
O <sub>2</sub> FLOW HI	At 1.0 lb/hr	None	FLOW O <sub>2</sub> indicator	C/M	
AC BUS 1 OVERLOAD	1. 30 at 9 amp/0 for 15±5 sec 2. 10 at 11 amp for 5±1 sec	None	AC VOLTS meter	C/M	Overload disconnects inverter from bus.
AC BUS 2 OVERLOAD	1. 30 at 9 amp/0 for 15±5 sec 2. 10 at 11 amp for 5±1 sec	None	AC VOLTS meter	C/M	Overload disconnects inverter from bus.

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2.10.6 TELEMETRY MEASUREMENTS

The following is a complete list of all C&WS telemetry data that is monitored by flight controllers and ground support personnel. The last column contains the name and type of S/C crew display. The display utilizes the same pickoff or signal source as telemetry, unless a separate measurement number is included in the display column.

Measurement Number	Description	Sensor Range	Crew Display
CS0150X	Master caution-warning on	Off/on event	MASTER ALARM lights

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SECTION 2

SUBSECTION 2.11

MISCELLANEOUS SYSTEMS DATA

2.11.1 INTRODUCTION.

Miscellaneous systems data pertains to items that were not covered in a previous system. These items consist of clocks, timers, accelerometers (G-meter), interior lighting, etc.

2.11.2 CLOCKS.

Two clocks and two clock-like event timers, all mechanical, are provided for the crew in the command module. The 400-hour clock (MDC-12), used in monitoring mission elapsed time, is illuminated by floodlights. The GMT 24-hour clock and two 10-hour event timers are located on panel 306 in the LH forward equipment bay and lighted by integral bulbs controlled by the CLOCKS-BRT/OFF/DIM switch on LEB 100. For further information, refer to section 4.

2.11.3 DIGITAL EVENT TIMERS.

The digital event timers provide the crew with a means of monitoring and timing events. One event timer is located on MDC-5 the other is located on MDC-11. The event timers start automatically when lift-off occurs, and the timer located on MDC-5 will be reset if an abort is automatically or manually initiated. For further information, refer to section 3.

2.11.4 ACCELEROMETER (G-METER).

The accelerometer or G-meter (MDC-2), provides the crew with a visual indication of spacecraft positive and negative G-loads. This meter is illuminated by floodlights controlled by the LH area control panel (MDC-26). For detailed information on the accelerometer (G-meter), refer to section 4.

2.11.5 COMMAND MODULE INTERIOR LIGHTING.

The interior lighting provides light for the main display console and LEB panels in the command module.

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2.11.5.1      Functional Description.

The interior lighting equipment consists of eight floodlight fixture assemblies and three control panels. Each fixture assembly contains two fluorescent lamps (one primary and one secondary) and a converter. The interior lighting is powered by 28 volts dc from main buses A and B for redundancy (figure 2.11-1). This assures a power source for lights in all areas in the event that either bus fails. The converter in each floodlight fixture converts 28 volts dc to a-c power to operate the fluorescent lamps. The floodlights are used to light three areas: the main display console (left and right areas) and the LEB area. Control panel (MDC-26) is located on the left and control panel (MDC-23) is located on the right of the main display console (figure 2.11-2). The third control panel is located in the lower equipment bay area on LEB-100. The floodlight fixtures are located around the interior of the command module. (See figure 2.11-2.)

Each control panel has a primary and secondary control for the floodlights in its respective area. The primary control is a rheostat that controls brightness of the primary floodlights. The secondary control is an ON-OFF switch for the secondary floodlights and is turned to ON when additional brightness is desired. The floodlight circuit breakers are on MDC-25. The operational use, or brightness level of the floodlights depends on two factors: the g-level and the task being performed. The floodlights should be turned up bright during ascent and entry. The floodlights will be adjusted as required while in earth orbit. The FDAI (MDC-4) is lighted by integral bulbs which are controlled by the FDAI LTG switch on MDC-25 and FDAI BRIGHTNESS rheostat on MDC-2. A switch is provided on the LEB floodlight control panel to control lighting for the clocks on LHFEB-306.

2.11.6      COMMAND MODULE UPRIGHTING SYSTEM.

The C/M uprighting system is manually controlled and operated after the C/M has assumed a stable inverted floating attitude. The system consists of three inflatable air bags, two relays, three solenoid control valves, two air compressors, control switches, and air lines. The inflatable bags are located in the C/M forward compartment and the air compressors are located in the aft compartment. The control switches and circuit breakers are located in the crew compartment. Switches 1 and 2 are powered by the postlanding bus switch 3 and the compressors are powered by battery buses A and B. (See figure 2.11-3.)

2.11.6.1      Functional Description.

POSTLANDING - FLOAT BAG switch 1 controls inflation of the air bag on +Y axis, switch 2 controls inflation of the air bag on the -Y axis, and switch 3 controls inflation of the air bag on the +Z axis of the C/M. (See figure 2.11-3.) Each bag is 43 inches in diameter and has a capacity of approximately 24 cubic feet when inflated. If the C/M becomes inverted

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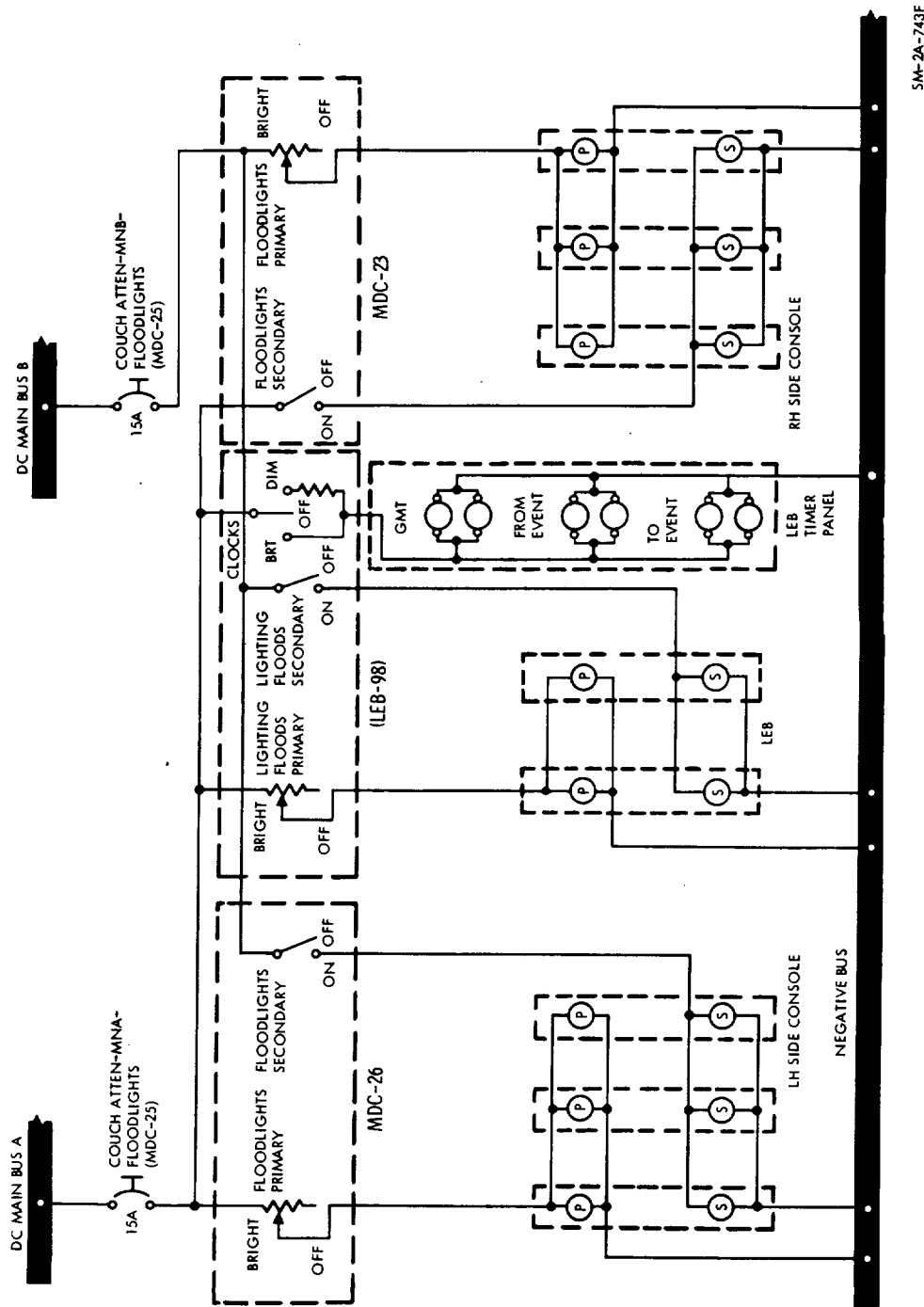


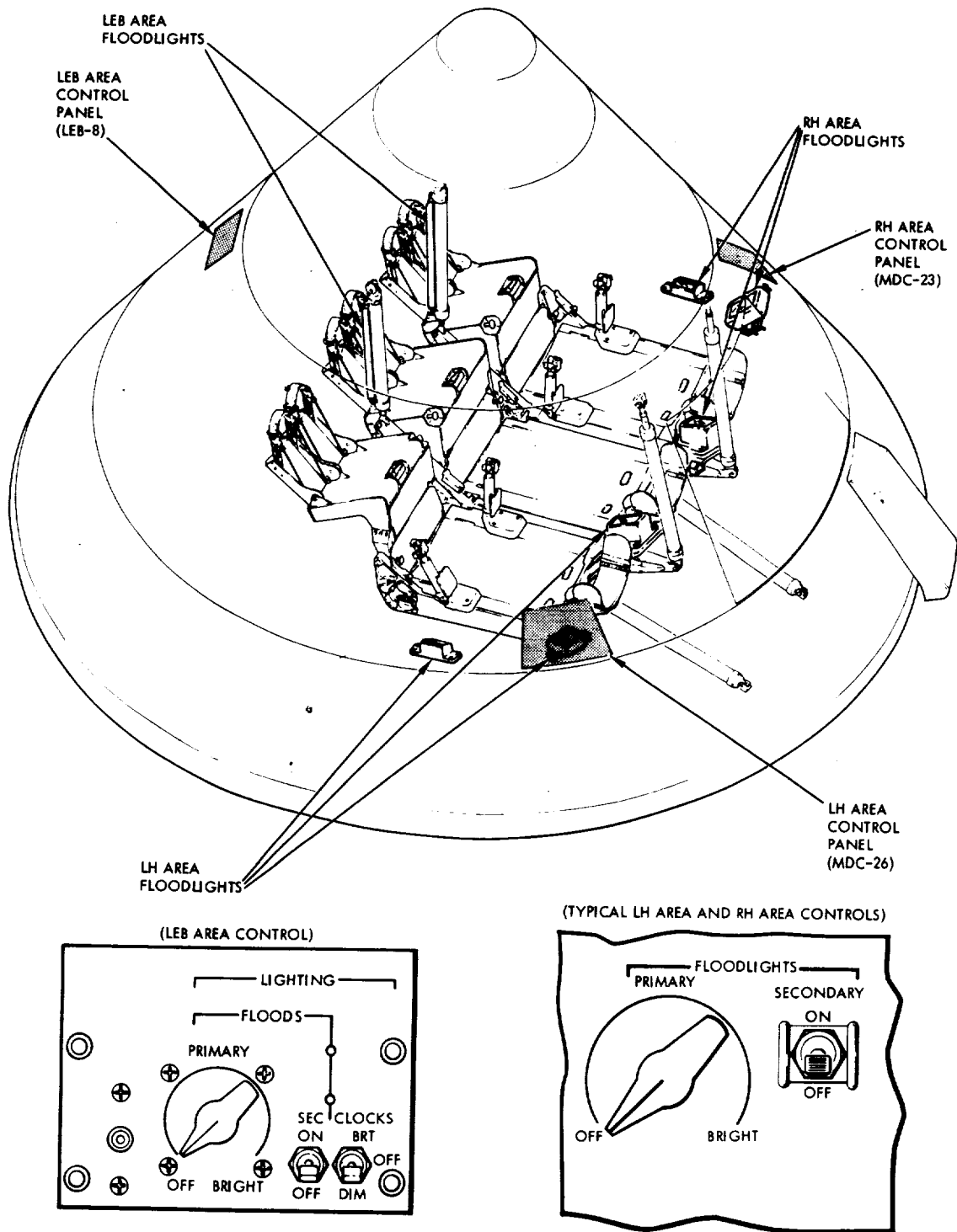
Figure 2.11-1. C/M Interior Lighting Schematic

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Figure 2.11-2. C/M Interior Lighting Configuration

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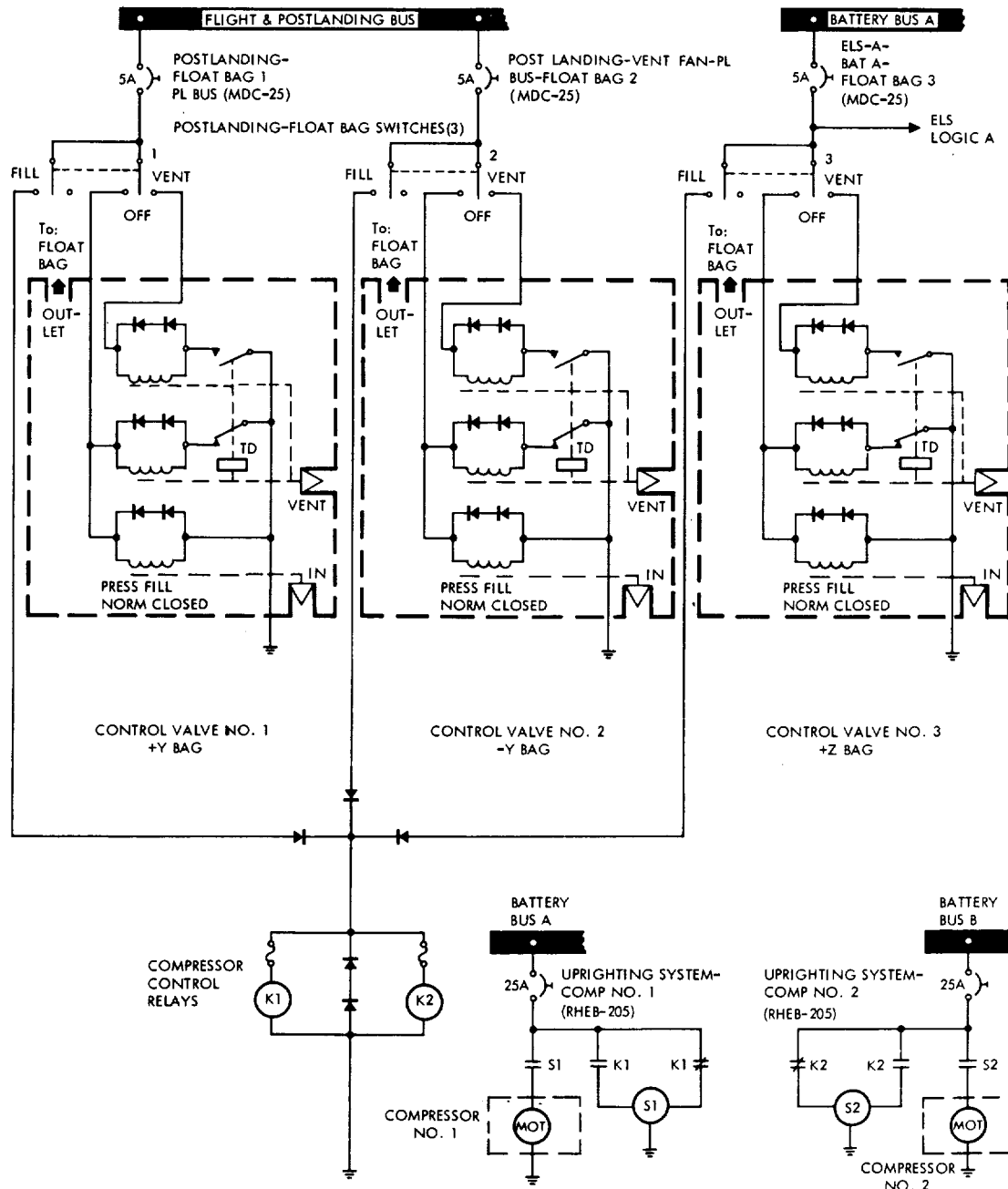


Figure 2.11-3. C/M Uprighting System Electrical Schematic

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after landing, the crewmember at station 1 initiates filling of the three bags by setting the POSTLANDING - FLOAT BAG switches 1, 2, and 3 to FILL. When the C/M is uprighted, the three FLOAT BAG switches will be set to OFF. A  $4.25 \pm 0.25$  psi relief valve is located in the inlet of each bag. Backup relief valves set at 13.5 psi are located in the outlet of each compressor.

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SECTION 3

CONTROLS AND DISPLAYS

INTRODUCTION.

This section identifies each control and display in the command module and lists panel location, item nomenclature, positions and related functions, power source, telemetry measurement number, and associated explanatory data. Controls and displays are presented in a tabulated list in numerical order by panel number. Panel numbers are those appearing on the main display console drawing and the lower equipment bay drawing in figure 3-1. (The command module itself does not incorporate numbers on the panels.) The following is a detailed explanation of the columnar data presented in the tabulated list.

Location	Gives the location of a particular control or display by panel number or other descriptive information such as "LH couch armrest, etc."
Name and Position	Gives the exact nomenclature of a particular control or display and the control positions, as placarded on the panel. In the absence of a placard, a functional name is assigned and the positions are described physically ("up," "down," etc).
Function	Describes the function of each control in each position.
Circuit Breaker	Gives the name and location of the circuit breaker(s) controlling the electrical power to each control & display.
Power Source	Identifies and gives the rating of the immediate bus or source supplying power to a particular control or display.
Telemetry Code No. and Identity	Gives the measurement numbers for telemetry signals which are used to monitor the performance of components, systems, and subsystems; the status of consumable items; and the proper sequencing of critical

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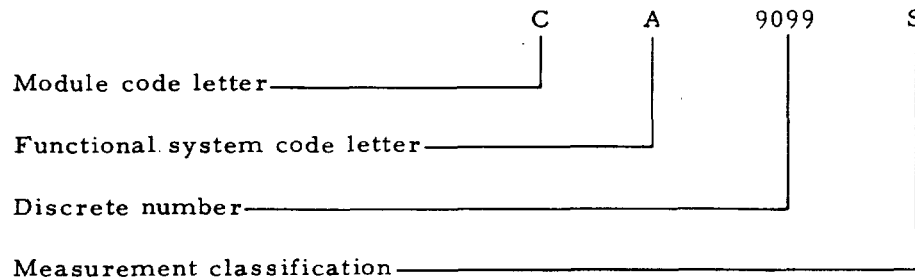
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operations during all phases of the spacecraft mission. This information is monitored at MSFN stations for spacecraft management from the ground by use of voice or command links. Measurement numbers are entered only for displayed measurements. Those for undisplayed measurements are included in the telemetry measurements table for the appropriate system in section 2 of this handbook.

The number consists of seven characters; two letters followed by four numbers and one letter. An example is as follows:



a. The first letter designates the module in which the measurement originates. Module code letters are as follows:

- |                  |                       |
|------------------|-----------------------|
| A Adapter        | L Launch escape tower |
| B Booster        | S Service module      |
| C Command module |                       |

b. The second letter denotes the system in which the measurement originates. Functional system code letters are as follows:

- |                             |  |
|-----------------------------|--|
| A Structures                | J Life systems                           |
| C Electrical power          | K Flight technology                      |
| D Launch escape             | P Propulsion                             |
| E Earth landing             | R Reaction control                       |
| F Environmental control     | S Crew safety                            |
| G Guidance and navigation   | T Telecommunications and instrumentation |
| H Stabilization and control |  |

c. Characters three through six are numerals comprising a number which is assigned to a particular measurement point. These numbers are listed sequentially or are grouped for clarity within each system.

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d. The seventh letter denotes measurement classification. Classification code letters are as follows:

A Acceleration	N Camera
B Phase	P Pressure
C Current	Q Quantity
D Vibration	R Rate
E Power	S Strain
F Frequency	T Temperature
G Force	V Voltage
H Position	W Time
J Biomedical	X Discrete event
K Radiation	Y Acoustical
L Velcotiy	Z pH - acidity
M Mass	

Remarks

Contains additional data and explanatory remarks.

3.1

CONTROLS/DISPLAYS LOCATOR INDEX.

To aid in finding data within this section, a locator index precedes the tabulated list. The index is sub-divided into spacecraft systems. Under each system is listed, in alphabetical order, all controls and displays associated with the particular system with cross reference to the panel on which the control or display is located. Where items, such as circuit breakers, are associated with more than one system, such items are repeated under each applicable system. Each panel number is preceded by an abbreviated descriptor to aid in quickly determining the general location of each item, as follows:

MDC	main display console (panels 1 thru 26)
LEB	lower equipment bay (panels 100 thru 107, 120, 150)
LHEB	left hand equipment bay (panels 307 thru 317 and 319)
LHFEB	left hand forward equipment bay (panels 300 thru 306 and 318)
RHEB	right hand equipment bay (panels 201 thru 206)
RHFEB	right hand forward equipment bay (panels 200 and 207)

The controls/displays locator index is sub-divided as follows:

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Control/Display Name	Type	Panel Locator
ACCEL FAIL	Lt	LEB-103
ACTIVITY COMP	Lt	MDC-14, LEB-106
AGC MODE	Sw	LEB-107
AGC PWR FAIL	Lt	MDC-10, LEB-103
ATT CONT MODE	Lt	LEB-101
ATTITUDE IMPULSE	Control	LEB-105
ATTITUDE IMPULSE ENABLE	Sw	LEB-105
BRIGHTNESS	Control	MDC-14, LEB-106
CDU FAIL	Lt	MDC-10, LEB-103
CDU MAN MODE	Lt	LEB-101
CHECK CONDITION LAMPS	Sw	LEB-105
CHECK COOLANT	Sw	LEB-105
CHECK COOLANT	Windows (2)	LEB-105
CHECK FAIL	Lt	LEB-106
CHECK MODE LAMPS	Sw	LEB-105
CLEAR	Sw	MDC-14, LEB-106
COARS ALIGN MODE	Lt	LEB-101
COMP FAIL	Lt	MDC-14
COMPUTER	CB (2)	MDC-22
CONDITION LAMP	Sw	LEB-105
COUNTER FAIL	Lt	LEB-106
DOOR LATCH	Control	LEB-105
DSKY	Keys	MDC-14, LEB-106
ENTER	Sw	MDC-14, LEB-106
ENTRY MODE	Lt	LEB-101
ERROR RESET	Sw	MDC-14, LEB-106
FINE ALIGN MODE	Lt	LEB-101
GMBL LOCK	Lt	MDC-10, LEB-103
G&N ACCEL FAIL	Lt	MDC-10
G&N ERROR	Lt	MDC-10
G&N VIEWER	Sw	MDC-22
IMU-CDU DIFFERENCE	Ind	LEB-101
IMU	CB (2)	MDC-22
IMU DELAY	Lt	LEB-103
IMU FAIL	Lt	MDC-10, LEB-103
IMU HTR	CB (2)	MDC-22
IMU TEMP	Lt	MDC-10, LEB-103
IMU TEMP MODE GAIN IRIG	Sw	LEB-105
IMU TEMP MODE GAIN PIPA	Sw	LEB-105
IMU TEMP MODE	Mode sw	LEB-105
IMU TEMP MODE ZERO	Sw	LEB-105
INNER GIMBAL (PITCH)	Ind	LEB-102
KEY RLSE	Lt	MDC-14, LEB-106
KEY RLSE	Sw	MDC-14, LEB-106
MANUAL ALIGN	Lt	LEB-101
MARK	Sw	LEB-105
MASTER ALARM	Lt	MDC-3, LEB-103

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Control/Display Name	Type	Panel Locator
MIDDLE GIMBAL (YAW)	Ind	LEB-102
-(minus sign switch)	Sw	MDC-14, LEB-106
NOUN	Sw	MDC-14, LEB-106
NOUN	End	MDC-14, LEB-106
OPTICS	CB (2)	MDC-22
OPTICS CONTROLLER MODE	Sw	LEB-105
OPTICS CONTROLLER SPEED	Sw	LEB-105
Optics hand controller (no placard)	Control	LEB-105
OPTICS HOLD	Sw	LEB-105
OPTICS	Mode sw	LEB-105
OPTICS SLAVE TELESCOPE	Sw	LEB-105
OUTER GIMBAL (ROLL)	Ind	LEB-102
PANEL BRIGHTNESS	Control	LEB-105
PARITY FAIL	Lt	LEB-106
PGNS	Lt	LEB-103
+ (plus sign switch)	Sw	MDC-14, LEB-106
PROG ALM	Lt	LEB-106
PROGRAM	Ind	MDC-14, LEB-106
REGISTER 1	Ind	MDC-14, LEB-106
REGISTER 2	Ind	MDC-14, LEB-106
REGISTER 3	Ind	MDC-14, LEB-106
RUPT LOCK	Lt	LEB-106
Sextant (not placarded)	SXT	LEB-104
SCALER FAIL	Lt	LEB-106
SHAFT ANGLE	Ind	LEB-102, LEB-104
SHAFT	Manual drive	LEB-104
Telescope (not placarded)	SCT	LEB-104
TC TRAP	Lt	LEB-106
TM FAIL	Lt	LEB-106
TRANSFER	Sw	LEB-101
TRUNNION ANGLE	Ind	LEB-104
TRUNNION	Manual drive	LEB-104
UPTTEL ACCEPT BLOCK	Sw	MDC-14
VERB	Ind	MDC-14, LEB-106
VERB	Sw	MDC-14, LEB-106
VIEWER	CB (2)	MDC-22
ZERO ENCODE MODE	Lt	LEB-101
ZERO ENCODER	Lt	LEB-103
2X TRUNNION	Ind	LEB-102

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Control/Display Name	Type	Panel Locator
AGAP TEMP	Warn lt	MDC-10
ATT DEADBAND	Sw	MDC-8
ATT SET	Sw	MDC-6
ATTITUDE IMPULSE-ENABLE	Sw	LEB-105
ATTITUDE/MONITOR/ENTRY	Sw	MDC-8
ATTITUDE SET-ROLL, PITCH, YAW	Thumbwheel (3)	MDC-6
ATTITUDE SET-ROLL, PITCH, YAW	Ind (3)	MDC-6
BMAG POWER	Sw	MDC-24
C/W-NORMAL/BOOST/ACK	Sw	MDC-13
CAUT/WARN-MNA, MNB	CB (2)	MDC-25
CAUTION/WARNING-MODE	Sw	MDC-11
DIRECT RCS	Sw	MDC-8
DIRECT ULLAGE	Sw	MDC-7
FCSM AUTO/OVERRIDE	Sw	MDC-2
FCSM ON/RESET	Sw	MDC-2
FDAI	Ind	MDC-4
FDAI ALIGN	Sw	MDC-6
FDAI BRIGHTNESS	Control	MDC-2
FDAI LTG	Sw	MDC-25
FDAI SELF TEST	Sw	MDC-2
.05G ENTRY	Sw	MDC-8
GIMBAL POSITION	Ind	MDC-6
G&N/SCS	Sw	MDC-8
G&N SYNC	Sw	MDC-25
LCL VERT	Sw	MDC-8
LIMIT CYCLE	Sw	MDC-8
MASTER EVENT SEQ CONT-A LOGIC B- BAT A, BAT B	CB (2)	MDC-22
NORMAL/OFF/DIRECT ON	Sw	MDC-7
PARTIAL SCS POWER	Sw	MDC-24
RATE GYRO POWER	Sw	MDC-24
RATE GYRO-ROLL, PITCH, YAW	Sw (3)	MDC-8
REACTION CONTROL SYS-TRANS	Sw	MDC-16
Rotational Controllers (not placarded)	Controls (2)	LH couch, RH arm- rest, RH couch, LH armrest
ROTATION CONTROL POWER	Sw	-24
SCS CHANNEL-A&C ROLL, B&D ROLL, PITCH, YAW	Sw (4)	MDC-8
STABILIZATION & CONTROL SYSTEM- A&C ROLL-MNA, MNB B&D ROLL-MNA, MNB DIRECT CONT-MNA, MNB GROUP 1-AC1, AC2 GROUP 1-MNA, MNB GROUP 2-AC1, AC2 GROUP 2-MNA, MNB	CB (18)	MDC-25

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Control/Display Name	Type	Panel Locator
THRUST ON	Sw	MDC-7
Translational Controllers (not placarded)	Control (2)	LH couch, LH armrest
TVC 1 POWER	Sw	MDC-24
TVC 2 POWER	Sw	MDC-24
$\Delta V$	Sw	MDC-8
$\Delta V$ REMAINING	Ind	MDC-7
$\Delta V$ SET	Sw	MDC-7
YAW, PITCH	Thumbwheel (2)	MDC-6

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Control/Display Name	Type	Panel Locator
ABORT SYSTEM-TWR JETT SPS MODE-A (B) two	Sw	MDC-16
CAUT/WARN-MNA (MNB)	CB (2)	MDC-25
$\Delta V$	Sw	MDC-8
$\Delta V$ REMAINING	Sw	MDC-7
$\Delta V$ SET	Sw	MDC-7
DIRECT ULLAGE	Sw	MDC-7
FCSM-G&N	Sw	MDC-2
FCSM-SCS	Sw	MDC-2
G&N/SCS	Sw	MDC-8
GIMBAL POSITION-PITCH	Ind	MDC-6
GIMBAL POSITION-PITCH	Thumbwheel	MDC-6
GIMBAL POSITION-YAW	Ind	MDC-6
GIMBAL POSITION-YAW	Thumbwheel	MDC-6
H <sub>e</sub> TANK-PRESS	Ind	MDC-20
H <sub>e</sub> TANK-TEMP	Ind	MDC-20
INSTRUMENTS-ESS-MNA (MNB)	CB (2)	MDC-22
L/V AOA/SPS P <sub>c</sub>	Ind	MDC-3
L/V AOA/SPS P <sub>c</sub>	Sw	MDC-3
MASTER EVENT SEQ CONT-A LOGIC B-BAT A (BAT B)	CB (2)	MDC-22
NORMAL/OFF/DIRECT ON (Thrust)	Sw	MDC-7
OXID FLOW	Sw	MDC-20
OXID FLOW-DECREASE	Ind	MDC-20
OXID FLOW-INCREASE	Ind	MDC-20
PITCH GMBL DR FAIL	Status lts	MDC-11
PRESSURE-ENG INLET-FUEL	Ind	MDC-20
PRESSURE-ENG INLET-OX	Ind	MDC-20
PRESSURE-FUEL	Ind	MDC-20
PRESSURE-OX	Ind	MDC-20
QUANTITY-FUEL	Display	MDC-20
QUANTITY-OXID	Display	MDC-20
SENSOR	Sw	MDC-20
SERVICE PROPULSION SYSTEM-		
GAUGING-AC1 (AC2)	CB (2)	MDC-25
GAUGING-MNA (MNB)	CB (2)	MDC-25
GIMBAL MOTOR CONTROL -1 PITCH -BAT A (PITCH 2-BAT B)	CB (2)	MDC-25
GIMBAL MOTOR CONTROL -1 YAW -BAT A (YAW 2-BAT B)	CB (2)	MDC-25
H <sub>e</sub> VALVE-MNA (MNB)	CB (2)	MDC-25
SPS ENGINE INJECT VALVE -1 (2, 3, 4)	Ind (4)	MDC-20
SPS GAUGING	Sw	MDC-25
SPS HELIUM (left hand and right hand)	Ind (2)	MDC-20
SPS HELIUM (left hand and right hand)	Sw (2)	MDC-20
SPS-INJECT PRE-VALVES-A (B)	Sw (2)	MDC-3
SPS-GIMBAL MOTORS -1 PITCH (PITCH 2)	Sw (2)	MDC-3

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Control/Display Name	Type	Panel Locator
SPS-GIMBAL MOTORS -1 YAW (YAW 2)	Sw (2)	MDC-3
SPS LINE HTR	Sw	MDC-19
SPS PRESS	Status lts	MDC-11
SPS PU SNSR FAIL	Status lts	MDC-11
SPS ROUGH ECO	Status lts	MDC-10
SPS TANK PRESS	Sw	MDC-20
STABILIZATION & CONTROL SYSTEM		
-DIRECT CONT-MNA (MNB)	CB (2)	MDC-25
-1 GROUP-AC 1 (GROUP 2-AC 2)	CB (2)	MDC-25
-1 GROUP-MNA (GROUP 2-MNB)	CB (2)	MDC-25
TELECOMMUNICATIONS—GROUP 5	CB	MDC-22
TEST/AUTO/TEST (propellant quantity)	Sw	MDC-20
THRUST ON	Switch-light	MDC-7
TK PRESS-N <sub>2</sub>	Ind	MDC-20
UNBALANCE	Ind	MDC-20
VALVE	Sw	MDC-20

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Control/Display Name	Type	Panel Locator
ABORT SYSTEM—OX DUMP	Sw	MDC-16
CM PROP JETT—DUMP	Sw	MDC-8
CM PROP JETT—LOGIC	Sw	MDC-8
CM PROP JETT—PURGE	Sw	MDC-8
C/M RCS	Sw	MDC-26
C/M RCS A	Status lts	MDC-10
C/M RCS B	Status lts	MDC-10
C/M RCS HTRS	Sw	RHFEB-200
C/M RCS PRESS F	Ind	MDC-12
C/M RCS TEMP H <sub>e</sub>	Ind	MDC-12
C/M RCS PRESS OX	Ind	MDC-12
C/M RCS PRPLNT—A	Sw	MDC-15
C/M RCS PRPLNT—A	Event ind	MDC-15
C/M RCS PRPLNT—B	Sw	MDC-15
C/M RCS PRPLNT—B	Event ind	MDC-15
C/M RCS TEMP H <sub>e</sub>	Ind	MDC-12
C/M-S/M-SEP-A (B)	Sw (2)	MDC-15
DIRECT RCS	Sw	MDC-8
INSTRUMENTS—ESS—MNA (MNB)	CB (2)	MDC-22
MASTER EVENT SEQ CONT		
-A ARM B—BAT A (BAT B)	CB (2)	MDC-22
-A LOGIC B—BAT A (BAT B)	CB (2)	MDC-22
PROPELLANT QUANTITY—FUEL (bottom window)	Digital ind	MDC-12
PROPELLANT QUANTITY—OXIDIZER (top window)	Digital ind	MDC-12
PYRO A—RCS FUEL DUMP	CB	LEB-150
PYRO B—RCS FUEL DUMP	CB	LEB-150
RCS HEATERS—A MNB	CB	MDC-21
RCS HEATERS—B MNA	CB	MDC-21
RCS HEATERS—C MNB	CB	MDC-21
RCS HEATERS—D MNA	CB	MDC-21
RCS INDICATORS selector		
C/M section	Sw	MDC-12
S/M section	Sw	MDC-12
REACTION CONTROL SYS—CMD	Sw	MDC-16
REACTION CONTROL SYS—C/M PRESS	Sw	MDC-16
REACTION CONTROL SYS—TRANS	Sw	MDC-16
REACTION CONTROL SYSTEM		
-C/M-S/M TRANSFER—MNA (MNB)	CB (2)	MDC-25
-GAUGING—MNA (MNB)	CB (2)	MDC-25
-PROP ISOL—MNA (MNB)	CB (2)	MDC-25
S/M RCS—A (B, C, D)—HELIUM 1	Sw (4)	MDC-15
S/M RCS—A (B, C, D)—HELIUM 1	Event ind (4)	MDC-15
S/M RCS—A (B, C, D)—HELIUM 2	Sw (4)	MDC-15
S/M RCS—A (B, C, D)—HELIUM 2	Event ind (4)	MDC-15
S/M RCS PRESS H <sub>e</sub>	Ind	MDC-12

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Control/Display Name	Type	Panel Locator
S/M RCS PRESS MANF	Ind	MDC-12
S/M RCS-A (B, C, D)-PROPELLANT	Event ind (4)	MDC-15
S/M RCS-A (B, C, D)-PROPELLANT	Sw (4)	MDC-15
S/M RCS TEMP PKG	Ind	MDC-12
S/M RCS A	Status lts	MDC-10
S/M RCS B	Status lts	MDC-10
S/M RCS C	Status lts	MDC-10
S/M RCS D	Status lts	MDC-10

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Control/Display Name	Type	Panel Locator
AC BUS 1 FAIL	Lt	MDC-11
AC BUS 2 FAIL	Lt	MDC-11
AC BUS 1 OVERLOAD	Lt	MDC-11
AC BUS 2 OVERLOAD	Lt	MDC-11
AC INDICATORS	Sw	MDC-18
AC INVERTER—AC BUS 1-RESET	Sw	MDC-18
AC INVERTER—AC BUS 2-RESET	Sw	MDC-18
AC INVERTER—1	Sw	MDC-18
AC INVERTER—1-AC BUS 1	Sw	MDC-18
AC INVERTER—1-AC BUS 2	Sw	MDC-18
AC INVERTER—2	Sw	MDC-18
AC INVERTER—2-AC BUS 1	Sw	MDC-18
AC INVERTER—2-AC BUS 2	Sw	MDC-18
AC INVERTER—3	Sw	MDC-18
AC INVERTER—3-AC BUS 1	Sw	MDC-18
AC INVERTER—3-AC BUS 2	Sw	MDC-18
AC SNSR SIG-AC1	CB	MDC-25
AC SNSR SIG-AC2	CB	MDC-25
AC VOLTS	Meter	MDC-18
BAT A PWR-ENTRY	CB	LEB-150
BAT B PWR-ENTRY	CB	LEB-150
BAT CHGR	Sw	MDC-22
BAT CHGR-BAT C	CB	LEB-150
BAT C PWR-POSTLANDING ENTRY	CB	LEB-150
BAT RLY BUS-BAT A	CB	MDC-22
BAT RLY BUS-BAT B	CB	MDC-22
BATTERY CHARGER	Sw	MDC-18
BATTERY CHARGER-AC PWR	CB	MDC-22
BATTERY CHARGER-BAT A CHGE	CB	MDC-22
BATTERY CHARGER-BAT B CHGE	CB	MDC-22
BATTERY CHARGER-MNA	CB	MDC-22
BATTERY CHARGER-MNB	CB	MDC-22
CRYOGENIC SYSTEM-QTY AMPL-AC 1-0C	CB	MDC-22
CRYOGENIC SYSTEM-QTY AMPL-AC 2-0C	CB	MDC-22
CRYOGENIC SYSTEM-TANK HEATERS-H <sub>2</sub>	CB	MDC-22
CRYOGENIC SYSTEM-TANK HEATERS-O <sub>2</sub>	CB	MDC-22
CRYOGENIC TANK FAN MOTORS-AC 1-0A	CB	MDC-22
CRYOGENIC TANK FAN MOTORS-AC 1-0B	CB	MDC-22
CRYOGENIC TANK FAN MOTORS-AC 1-0C	CB	MDC-22
CRYOGENIC TANK FAN MOTORS-AC 2-0A	CB	MDC-22
CRYOGENIC TANK FAN MOTORS-AC 2-0B	CB	MDC-22
CRYOGENIC TANK FAN MOTORS-AC 2-0C	CB	MDC-22
DC AMPS	Meter	MDC-18
DC INDICATORS	Sw	MDC-18
DC SNSR SIG-MNA	CB	MDC-22
DC SNSR SIG-MNB	CB	MDC-22
DC VOLTS	Meter	MDC-18

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Control/Display Name	Type	Panel Locator
DC VOLTS (auxiliary)	Meter	RHFEB-200
F/C-BUS DISCONNECT	Lt	MDC-11
F/C RAD TEMP LOW	Ind	MDC-18
F/C VALVES	Sw	MDC-19
F/C 1	Lt	MDC-11
F/C 2	Lt	MDC-11
F/C 3	Lt	MDC-11
FREQUENCY	Meter	MDC-18
FUEL CELL-FLOW-H <sub>2</sub>	Ind	MDC-18
FUEL CELL-FLOW-O <sub>2</sub>	Ind	MDC-18
FUEL CELL INDICATORS	Sw	MDC-18
FUEL CELL-MAIN BUS A-RESET	Sw	MDC-18
FUEL CELL-MAIN BUS B-RESET	Sw	MDC-18
FUEL CELL-MODULE TEMP-COND EXH	Ind	MDC-18
FUEL CELL-MODULE TEMP-SKIN	Ind	MDC-18
FUEL CELL 1-BUS CONT	CB	MDC-22
FUEL CELL 1-CIR & SEP MOTORS	CB	MDC-22
FUEL CELL 1-H <sub>2</sub> &O <sub>2</sub> VALVE	CB	MDC-22
FUEL CELL 1-PURGE	CB	MDC-22
FUEL CELL-1-MAIN BUS A	Ind	MDC-18
FUEL CELL-1-MAIN BUS A	Sw	MDC-18
FUEL CELL-1-MAIN BUS B	Ind	MDC-18
FUEL CELL-1-MAIN BUS B	Sw	MDC-18
FUEL CELL-1 purge	Sw	MDC-18
FUEL CELL-1-REACTANTS	Ind	MDC-18
FUEL CELL-1-REACTANTS	Sw	MDC-18
FUEL CELL 2-BUS CONT	CB	MDC-22
FUEL CELL 2-CIR & SEP MOTORS	CB	MDC-22
FUEL CELL 2-H <sub>2</sub> &O <sub>2</sub> VALVE	CB	MDC-22
FUEL CELL 2-PURGE	CB	MDC-22
FUEL CELL-2-MAIN BUS A	Ind	MDC-18
FUEL CELL-2-MAIN BUS A	Sw	MDC-18
FUEL CELL-2-MAIN BUS B	Ind	MDC-18
FUEL CELL-2-MAIN BUS B	Sw	MDC-18
FUEL CELL-2 purge	Sw	MDC-18
FUEL CELL-2-REACTANTS	Ind	MDC-18
FUEL CELL-2-REACTANTS	Sw	MDC-18
FUEL CELL 3-BUS CONT	CB	MDC-22
FUEL CELL 3-CIR & SEP MOTORS	CB	MDC-22
FUEL CELL 3-H <sub>2</sub> &O <sub>2</sub> VALVE	CB	MDC-22
FUEL CELL 3-PURGE	CB	MDC-22
FUEL CELL-3-MAIN BUS A	Ind	MDC-18
FUEL CELL-3-MAIN BUS A	Sw	MDC-18
FUEL CELL-3-MAIN BUS B	Ind	MDC-18
FUEL CELL-3-MAIN BUS B	Sw	MDC-18
FUEL CELL-3 purge	Sw	MDC-18
FUEL CELL-3-REACTANTS	Ind	MDC-18
FUEL CELL-3-REACTANTS	Sw	MDC-18

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Control/Display Name	Type	Panel Locator
FUEL CELL PUMP-1	Sw	MDC-22
FUEL CELL PUMP-2	Sw	MDC-22
FUEL CELL PUMP-3	Sw	MDC-22
FUNCTION SELECT	Sw	RHFEB-200
H <sub>2</sub> FANS-1	Sw	MDC-13
H <sub>2</sub> FANS-2	Sw	MDC-13
H <sub>2</sub> HEATERS-1	Sw	MDC-13
H <sub>2</sub> HEATERS-2	Sw	MDC-13
H <sub>2</sub> PRESS	Lt	MDC-10
INVERTER CONTROL-1	CB	MDC-22
INVERTER CONTROL-2	CB	MDC-22
INVERTER CONTROL-3	CB	MDC-22
INVERTER PWR-NO. 1 MNA	CB	RHEB-203
INVERTER PWR-NO. 2 MNB	CB	RHEB-203
INVERTER PWR-NO. 3 MNA	CB	RHEB-203
INVERTER PWR-NO. 3 MNB	CB	RHEB-203
INV 1 TEMP HI	Lt	MDC-11
INV 2 TEMP HI	Lt	MDC-11
INV 3 TEMP HI	LT	MDC-11
MAIN A-BAT BUS A	CB	RHEB-203
MAIN A-BAT C	CB	RHEB-203
MAIN B-BAT BUS B	CB	RHEB-203
MAIN B-BAT C	CB	RHEB-203
MAIN BUS TIE-BAT A&C	Sw	MDC-22
MAIN BUS TIE-BAT B&C	Sw	MDC-22
MN BUS A UNDERVOLT	Lt	MDC-11
MN BUS B UNDERVOLT	Lt	MDC-11
NON ESS BUS	Sw	MDC-22
O <sub>2</sub> FANS-1	Sw	MDC-13
O <sub>2</sub> FANS-2	Sw	MDC-13
O <sub>2</sub> HEATERS-1	Sw	MDC-13
O <sub>2</sub> HEATERS-2	Sw	MDC-13
O <sub>2</sub> PRESS	Lt	MDC-10
pH HI	Ind	MDC-18
POST LDG-BAT BUS A	CB	RHEB-203
POST LDG-BAT BUS B	CB	RHEB-203
POST LDG-BAT C	CB	RHEB-203
POST LDG-MAIN A	CB	RHEB-203
POST LDG-MAIN B	CB	RHEB-203
REG OUT PRESS HI-H <sub>2</sub>	Ind	MDC-18
REG OUT PRESS HI-N <sub>2</sub>	Ind	MDC-18
REG OUT PRESS HI-O <sub>2</sub>	Ind	MDC-18
SNSR UNIT-AC BUS-1	CB	MDC-21
SNSR UNIT-AC BUS-2	CB	MDC-21
SNSR UNIT-DC BUS-A	CB	MDC-21
SNSR UNIT-DC BUS-B	CB	MDC-21

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Control/Display Name	Type	Panel Locator
TANK PRESSURE-H <sub>2</sub> -1	Ind	MDC-13
TANK PRESSURE-H <sub>2</sub> -2	Ind	MDC-13
TANK PRESSURE-O <sub>2</sub> -1	Ind	MDC-13
TANK PRESSURE-O <sub>2</sub> -2	Ind	MDC-13
TANK QUANTITY-H <sub>2</sub> -1	Ind	MDC-13
TANK QUANTITY-H <sub>2</sub> -2	Ind	MDC-13
TANK QUANTITY-O <sub>2</sub> -1	Ind	MDC-13
TANK QUANTITY-O <sub>2</sub> -2	Ind	MDC-13
TEST SELECT	Sw	RHFEB-200
H <sub>2</sub> PURGE LINE HTR	Sw	MDC-15
INV. PHASE LOCK	Sw	RHEB 208

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Control/Display Name	Type	Panel Locator
ABORT	Lt	MDC-3
ABORT SYSTEM-MODE	Sw (2)	MDC-16
ABORT SYSTEM-L/V RATES	Sw	MDC-16
ABORT SYSTEM-OX DUMP	Sw	MDC-16
ABORT SYSTEM-2 ENG OUT	Sw	MDC-16
ADAPT SEP	Sw	MDC-5
ALTIMETER	Indicator	MDC-1
APEX COVER JETT	Sw	MDC-5
CANARD DEPLOY	Sw	MDC-5
C/M-S/M SEP	Sw (2)	MDC-15
COUCH UNLOCK	Sw	MDC-8
Digital Event Timer Indicator (no placard)	Window	MDC-5
DIGITAL EVENT TIMER-MIN	Sw	MDC-8
DIGITAL EVENT TIMER-RESET	Sw	MDC-8
DIGITAL EVENT TIMER-SEC	Sw	MDC-8
DIGITAL EVENT TIMER-START	Sw	MDC-8
Digital Event Timer Indicator (no placard)	Window	MDC-11
DIGITAL EVENT TIMER-MIN	Sw	MDC-11
DIGITAL EVENT TIMER-RESET	Sw	MDC-11
DIGITAL EVENT TIMER-SEC	Sw	MDC-11
DIGITAL EVENT TIMER-START	Sw	MDC-11
DROGUE DEPLOY	Sw	MDC-5
EDS	Sw	MDC-16
EDS	CB (3)	MDC-25
EDS POWER	Sw	MDC-24
ELS	CB (3)	MDC-25
ELS LOGIC	Sw	MDC-8
EVENT TIMER	CB (2)	MDC-25
LES MOTOR FIRE	Sw	MDC-5
LIFT-OFF	Lt	MDC-5
LOCK/UNLOCK	Control	MDC-5
L/V AOA/SPS PC	Ind	MDC-3
L/V AOA/SPS PC	Sw	MDC-3
L/V ENGINE	Lt (8)	MDC-5
L/V GUID	Lt	MDC-5
L/V RATE	Lt	MDC-5
MAIN CHUTE RELEASE	Sw	MDC-16
MAIN DEPLOY	Sw	MDC-5
MAIN DEPLOY-AUTO	Sw	MDC-16
MASTER EVENT SEQ CONT-ARM	CB (2)	MDC-22
MASTER EVENT SEQ CONT-LOGIC	CB (2)	MDC-22
MASTER EVENT SEQ CONT-PYRO ARM	Sw (2)	MDC-24
MESC-LOGIC ARM	Sw (2)	MDC-25
NO AUTO ABORT	Lt	MDC-5
POST LDG BEACON LIGHTS	Sw	MDC-26
PYRO A-RCS FUEL DUMP	CB	LEB-150
PYRO A-SEQ A	CB	LEB-150
PYRO B-RCS FUEL DUMP	CB	LEB-150
PYRO B-SEQ B	CB	LEB-150

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TELECOMMUNICATIONS—CONTROLS/DISPLAYS LOCATOR INDEX

Control/Display Name	Type	Panel Locator
BIO-MED COMM-MNA	CB	MDC-25
BIO-MED COMM-MNB	CB	MDC-25
C-BAND	Sw	MDC-20
CENTRAL TIMING SYS-MNA	CB	MDC-22
CENTRAL TIMING SYS-MNB	CB	MDC-22
FLIGHT QUAL RCDR	Sw	MDC-19
RCDR/HF	Sw	MDC-13, -23, -26
INST PWR CONT		RHEB-204
ESSENTIAL 1 THRU 4	CB (4)	
NON-ESSENTIAL 5 THRU 10	CB (6)	
INSTRUMENTS-ESS-MNA	CB	MDC-22
INSTRUMENTS-ESS-MNB	CB	MDC-22
INSTRUMENTS-NONESS	CB	MDC-22
INSTRUMENTS-NONESS BUS	CB	MDC-22
INSTRUMENTS-RCDR NONESS	CB	MDC-22
INSTRUMENTS-SCIEN	CB	MDC-22
INTERCOM	Sw	MDC-13, -23, -26
INTERCOM BALANCE	Sw	MDC-13, -23, -26
NONESS BUS	Sw	MDC-22
POSTLANDING ANTENNA DEPLOY	Sw	MDC-25
POWER		MDC-13, -23, -26
POWER-PMP	Sw	MDC-20
POWER-SCE	Sw	MDC-20
RECOVERY-HF-ON/OFF	Sw	MDC-20
RECOVERY-HF-SSB/BCN/AM	Sw	MDC-20
RECOVERY-VHF BCN	Sw	MDC-20
S-BAND	Sw	MDC-13, -23, -26
S-BAND ANT	Ind	MDC-19
S-BAND ANTENNA	Sw	MDC-20
S-BAND-EMERG	Sw	MDC-20
S-BAND-OSC	Sw	MDC-20
S-BAND-PWR AMPL	Sw	MDC-20
S-BAND-VOICE-RNG/RNG ONLY	Sw	MDC-20
S-BAND-VOICE-TAPE	Sw	MDC-20
S-BAND-VOICE-TV	Sw	MDC-20
S-BAND-XPONDER/XPONDER PWR AMPL	Sw	MDC-20
TAPE RECORDER-FWD/REV	Sw	MDC-20
TAPE RECORDER-PLAY	Sw	MDC-20
TAPE RECORDER-RECORD/PLAY	Sw	MDC-20
TAPE RECORDER-SPEED	Sw	MDC-20
TELECOM-ESS	Sw	MDC-22
TELECOM-NONESS	Sw	MDC-22
TELECOMMUNICATIONS-GROUP 1 AC	CB	MDC-22
TELECOMMUNICATIONS-GROUP 2 AC	CB	MDC-22
TELECOMMUNICATIONS-GROUP 3	CB	MDC-22
TELECOMMUNICATIONS-GROUP 4	CB	MDC-22
TELECOMMUNICATIONS-GROUP 5	CB	MDC-22

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Control/Display Name	Type	Panel Locator
TELECOMMUNICATIONS-PCM TLM AC	CB	MDC-22
TELECOMMUNICATIONS-SIG COND S-BAND PA AC	CB	MDC-22
TLM INPUTS-BIOMED	Sw	MDC-20
TLM INPUTS-PCM	Sw	MDC-20
UP DATA	Sw	MDC-20
UP TLM CMD	Sw	MDC-19
VHF-AM	Sw	MDC-13, -23, -26
VHF-AM RCVR	Sw	MDC-20
VHF-AM SQUELCH	Control	MDC-20
VHF-AM-T/R/REC	Sw	MDC-20
VHF-ANTENNA	Sw	MDC-20
VHF-FM	Sw	MDC-20
VOICE RECORD	Indicator	MDC-19
VOLUME	Control	MDC-13, -23, -26
VOX SENS	Control	MDC-13, -23, -26

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Control/Display Name	Type	Panel Locator
BATTERY VENT	Valve	RHEB-203
Cabin air control louver	Control	LHFEB-303
CABIN AIR/AUTO/SUIT AIR	Sw	LEB-120
CABIN AIR FAN-1 & 2	Sw (2)	MDC-21
CABIN PRESSURE RELIEF	Valve (2)	LHEB-307
CABIN REPRESS	Valve	LHEB-314
CABIN TEMP	Valve	LHFEB 303
CABIN TEMP-AUTO	Control	MDC-13
CABIN TEMP-AUTO/MAN	Sw	MDC-13
CO <sub>2</sub> -odor absorber diverter	Valve	LHEB-313
CO <sub>2</sub> PP HI	Light	MDC-11
DIRECT O <sub>2</sub>	Valve	MDC-24
DRINKING WATER SUPPLY	Valve	LHFEB-304
ΔP SUIT COMPR	Ind	MDC-13
ECS-CABIN AIR FAN-1 & 2	CB (6)	MDC-22
ECS-GLYCOL PUMPS-AC 1 & AC 2	CB (6)	MDC-22
ECS-GLYCOL-PUMP 1/PUMP 2	Sw (2)	MDC-21
ECS-H <sub>2</sub> O ACCUM-MNA & MNB	CB (2)	MDC-22
ECS-POT H <sub>2</sub> O HTR-MNA & MNB	CB (2)	MDC-22
ECS-RADIATOR	Sw (4)	MDC-21
ECS RAD-OUTLET TEMP	Ind	MDC-13
ECS RAD OUT TEMP-1 & 2	Ind (2)	MDC-19
ECS-RAD VALVE-AC 1 & AC 2	CB (4)	MDC-22
ECS STEAM DUCT HTR-MNA & MNB	CB (2)	RHEB-206
ECS-SUIT COMPRESSORS-AC 1 & AC 2	CB (6)	MDC-22
ECS-TRANSDUCER-PRESS GROUPS 1 & 2	CB (4)	MDC-22
ECS-TRANSDUCER-TEMP-MNA & MNB	CB (2)	MDC-22
ECS-TRANSDUCER-WASTE & POT H <sub>2</sub> O-MNA & MNB	CB (2)	MDC-22
EMERGENCY CABIN PRESSURE	Valve	LHEB-314
EVAP H <sub>2</sub> O	Valve	LHEB-311
FLOW O <sub>2</sub>	Ind	MDC-13
FOOD PREPARATION WATER-COLD & HOT	Valve (2)	LHFEB-305
GAS ANAL	CB	MDC-22
GLY ACCUM-QUANTITY	Ind	MDC-13
GLY EVAP WATER CONTROL BYPASS	Valve	LHEB-317
GLYCOL ACCUMULATOR	Valve	LHEB-312
GLYCOL EVAP-H <sub>2</sub> O FLOW	Sw	MDC-13
GLYCOL EVAP-STEAM PRESS-AUTO/MAN	Sw	MDC-13
GLYCOL EVAP-STEAM PRESS-INCR/DECR	Sw	MDC-13
GLYCOL EVAP-STEAM PRESS-TEMP IN	Sw	MDC-13
GLYCOL EVAP TEMP IN	Valve	LHEB-311
GLYCOL PRESS RELIEF BYPASS-1 & 2	Valve (2)	LHEB-309
GLYCOL RESERVE	Valve	LHEB-311
GLYCOL RESERVOIR-BYPASS	Valve	LHEB-307
GLYCOL RESERVOIR-INLET	Valve	LHEB-307
GLYCOL RESERVOIR-OUTLET	Valve	LHEB-307
GLYCOL TEMP LOW	Light	MDC-11

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Control/Display Name	Type	Panel Locator
GLYCOL TO RAD	Valve	LHEB-307
GLY EVAP-OUTLET TEMP	Ind	MDC-13
GLY EVAP STEAM PRESS	Ind	MDC-13
H <sub>2</sub> O ACCUM-AUTO/MAN	Sw	MDC-13
H <sub>2</sub> O ACCUM FAIL	Light	MDC-11
H <sub>2</sub> O ACCUM-ON 1/ON 2	Sw	MDC-13
H <sub>2</sub> O ACCUMULATOR-1 & 2	Valve (2)	LHEB-311
H <sub>2</sub> O IND	Sw	MDC-13
INST PWR CONT-ESSENTIAL 2	CB	RHEB-204
MAIN REGULATOR	Valve	LHEB-314
O <sub>2</sub> FLOW HI	Light	MDC-11
O <sub>2</sub> PRESS IND	Sw	MDC-13
OXYGEN-ENTRY	Valve	LHEB-307
OXYGEN-S/M SUPPLY	Valve	LHEB-307
OXYGEN-SURGE TANK	Valve	LHEB-307
PART PRESS CO <sub>2</sub>	Ind	MDC-13
PGA pressure	Ind (3)	PGA sleeve
PLSS FILL	Valve	LHEB-314
PLVC	Sw	LHEB-316
POST LANDING-VENT FAN	Sw	MDC-25
POST LANDING-VENT FAN-PL BUS/FLOAT BAG 2	CB	MDC-25
POTABLE TANK INLET	Valve	LHEB-315
POT H <sub>2</sub> O HEATER	Sw	MDC-21
PRESS-CABIN	Ind	MDC-13
PRESS GLY DISCH	Ind	MDC-13
PRESS-SUIT	Ind	MDC-13
PRESSURE RELIEF	Valve	LHEB-315
START/OFF/PREHEAT	Sw	LEB-120
Suit circuit return air	Valve	LHEB-319
SUIT COMPRESSOR-COMPR 1/COMPR 2	Sw	MDC-21
Suit demand pressure regulator selector	Valve	LHEB-310
SUIT EVAP	Sw	MDC-13
SUIT EVAP	Valve	LHEB-311
SUIT EVAP GLYCOL	Valve	LHEB-311
SUIT FLOW	Valve (3)	LHFEB-300, -301, -302
SUIT FLOW RELIEF	Valve	LHEB-311
SUIT HT EXCH	Sw	LHEB-310
SUIT TEST	Valve	LHEB-310
SURGE TANK PRESSURE RELIEF	Valve	LHEB-308
TANK PRESSURE-O <sub>2</sub> -1	Ind	MDC-13
TEMP-CABIN	Ind	MDC-13
TEMP-SUIT	Ind	MDC-13
WASTE H <sub>2</sub> O TK REFILL	Sw	MDC-13
WASTE MANAGEMENT-OVBD DRAIN	Valve	RHEB-201
WASTE MANAGEMENT-SELECTOR	Valve	RHEB-201

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Control/Display Name	Type	Panel Locator
WASTE TANK INLET	Valve	LHEB-315
WASTE TANK SERVICING	Valve	LHEB 315
WATER & GLYCOL TANKS PRESSURE- REGULATOR-SELECTOR INLET	Valve	LHEB-314
WATER & GLYCOL TANKS PRESSURE- RELIEF-SELECTOR OUTLET	Valve	LHEB-314
WATER-QUANTITY	Ind	MDC-13

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CAUTION AND WARNING SYSTEM—LOCATOR INDEX

Control/Display Name	Type	Panel Locator
AC BUS 1 FAIL	Lt	MDC-11
AC BUS 2 FAIL	Lt	MDC-11
AC BUS 1 OVERLOAD	Lt	MDC-11
AC BUS 2 OVERLOAD	Lt	MDC-11
AGAP TEMP	Lt	MDC-10
AGC PWR FAIL	Lt	MDC-10
CAUT/WARN-FAIL	Lt	MDC-11
CAUT/WARN-MNA & MNB	CB (2)	MDC-25
CAUT/WARN-MODE	Sw	MDC-11
CAUT/WARN-POWER	Sw	MDC-11
CDU FAIL	Lt	MDC-10
C/M RCS A	Lt	MDC-10
C/M RCS B	Lt	MDC-10
CO <sub>2</sub> PP HI	Lt	MDC-11
C/W	Sw	MDC-13
C/W LAMP TEST	Sw	MDC-23
F/C 1	Lt	MDC-11
F/C 2	Lt	MDC-11
F/C 3	Lt	MDC-11
F/C BUS DISCONNECT	Lt	MDC-11
GLYCOL TEMP LOW	Lt	MDC-11
GMBL LOCK	Lt	MDC-10
G&N ACCEL FAIL	Lt	MDC-10
G&N ERROR	Lt	MDC-10
H <sub>2</sub> O ACCUM FAIL	Lt	MDC-11
H <sub>2</sub> PRESS	Lt	MDC-10
IMU FAIL	Lt	MDC-10
IMU TEMP	Lt	MDC-10
INV 1	Lt	MDC-11
INV 2	Lt	MDC-11
INV 3	Lt	MDC-11
MASTER ALARM	Lt	MDC-3
MASTER ALARM	Lt	MDC-18
MASTER ALARM	Lt	LEB-103
MN BUS A UNDERVOLT	Lt	MDC-11
MN BUS B UNDERVOLT	Lt	MDC-11
O <sub>2</sub> FLOW HI	Lt	MDC-11
O <sub>2</sub> PRESS	Lt	MDC-10
PITCH GMBL DR FAIL	Lt	MDC-11
S/M RCS A	Lt	MDC-10
S/M RCS B	Lt	MDC-10
S/M RCS C	Lt	MDC-10
S/M RCS D	Lt	MDC-10
SPS PRESS	Lt	MDC-11
SPS PU SNSR FAIL	Lt	MDC-11
SPS ROUGH ECO	Lt	MDC-10
SPS WALL TEMP HI	Lt	MDC-11
YAW GMBL DR FAIL	Lt	MDC-11

CAUTION AND WARNING SYSTEM—LOCATOR INDEX

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MISCELLANEOUS SYSTEMS—CONTROLS/DISPLAYS LOCATOR INDEX

Controls/Display Name	Type	Panel Locator
COUCH ATTEN-FLOODLIGHTS	CB (2)	MDC-25
ELS-FLOAT BAG 3	CB	MDC-25
FLOODLIGHTS-PRIMARY	Sw	MDC-23
FLOODLIGHTS-SECONDARY	Sw	MDC-23
FLOODLIGHTS-PRIMARY	Sw	MDC-26
FLOODLIGHTS-SECONDARY	Sw	MDC-26
LIGHTING-CLOCKS	Sw	LEB-100
LIGHTING-FLOODS-PRIMARY	Sw	LEB-100
LIGHTING-FLOODS-SEC	Sw	LEB-100
POST LANDING-FLOAT BAG	Sw (3)	MDC-25
POST LANDING-FLOAT BAG 1 PL BUS	CB	MDC-25
POST LANDING-VENT FAN-PL BUS-FLOAT BAG 2	CB	MDC-25
UPRIGHTING SYSTEM-COMPR NO. 1 AND NO. 2	CB	RHEB-205

MISCELLANEOUS SYSTEMS—CONTROLS/DISPLAYS LOCATOR INDEX

Controls/Display Name	Type	Panel Locator
SCIEN EQUIP SEB 1	CB	MDC-22
SCIEN EQUIP SEB 2	CB	MDC-22
INSTRUMENTS—SCIEN (not used)	CB	MDC-22
SCIEN EQUIP HATCH	CB	MDC-22

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## CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-1	ALTIMETER	Indicates altitude of command module up to 60,000 feet.	None	None	None	The altimeter is monitored to verify deployment of the drogue and main parachutes at the proper altitude. An adjustable marker on the dial is set prior to launch. The marker is used as a reference for manual deployment of the main parachutes during an abort initiated prior to 61 seconds after lift-off.
MDC-2	FCSM controls G&N/RESET/OVERRIDE switch G&N	Receives power from the SCS- GROUP 1-MNA and B circuit breakers through the G&N mode switch, attitude mode switch, and $\Delta V$ switch in ON position. Applies power to the FCSM and the G&N, SCS $\Delta V$ gates. If unstable combustion is sensed, the FCSM automatically energizes relays that remove power from the G&N, SCS $\Delta V$ gates, automatically shutting the engine down; other relay contact points will illuminate the SPS ROUGH ECO caution and warning light on MDC-10.	SCS- GROUP 1 MNA MNB	G&N switch attitude switch V switch ON	None	Two-position toggle switch. Placed in G&N position when G&N $\Delta V$ mode is utilized.
	RESET/OVERRIDE	Applies power to the G&N, SCS $\Delta V$ gates, bypassing the FCSM system. If unstable combustion is sensed, the SPS engine will not shut down and the SPS ROUGH ECO caution and warning light on MDC-10 will not illuminate. Will also be utilized to RESET the FCSM system if an automatic shutdown has occurred.				Placed to this position when SCS $\Delta V$ mode is utilized.  The $\Delta V$ switch placed to OFF will also RESET the FCSM as a backup to the RESET/OVERRIDE position.
	SCS RESET/OVERRIDE switch	Receives power from the SCS GROUP 1 - MNA and B circuit breakers through the G&N mode switch, attitude mode switch, and the $\Delta V$ switch in ON position. Applies power to the FCSM and the SCS $\Delta V$ gates. If unstable combustion is sensed, the FCSM automatically energizes relays that remove power from the SCS $\Delta V$ gates, automatically shutting the engine down; other relay contact points will illuminate the SPS ROUGH ECO caution and warning light on MDC-10.				Two-position toggle switch.  Placed in SCS position when SCS $\Delta V$ mode is utilized.

MAIN DISPLAY CONSOLE— PANELS 1 AND 2

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CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-2	RESET/OVERRIDE	Applies power to the SCS $\Delta V$ gates bypassing the FCSM system. If unstable combustion is sensed, the SPS engine will not shut down and the SPS ROUGH ECO caution and warning light on MDC-10 will not illuminate. Will also be utilized to RESET the FCSM system if an automatic shutdown has occurred.	SCS - GROUP 1 MNA MNB	G&N switch attitude $\Delta V$ switch ON	None	Placed to this position when G&N $\Delta V$ mode is utilized.  The $\Delta V$ switch placed to OFF would also RESET the FCSM as a backup to the RESET/OVERRIDE position.
	LONG ACCEL indicator	Displays S/C positive and negative g loads along spacecraft X axis and records maximum g readings encountered. A RESET knob enables manual reset of recording pointers to normal 1g position.	(TBD)	(TBD)	(TBD)	The indicator has three pointers; one for normal g indications and the other two for recording maximum +g and -g readings, respectively. Scale +16 to -6g, readable increments 0.2g. Sensor is located behind instrument face.

MAIN DISPLAY CONSOLE—PANEL 2



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CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-2 (Cont)	FDAI BRIGHTNESS control  OFF	Turns off FDAI panel lighting (white light) (MDC-4) and THRUST ON switch face lighting (MDC-7).	SCS— GROUP 2 AC 1 AC 2 (MDC-25)	A-C buses No. 1 and No. 2	None	
	INCR	Adjusts intensity of FDAI panel lighting and THRUST ON switch face lighting. <sup>a</sup>				
MDC-3	FDAI SELF TEST switch  SELF TEST (up)	Normal SCS rate mode  a. Removes rate gyro input from SCS rate electronics. b. Applies test signal to SCS rate electronics, causing negative deflection of all FDAI rate indicators to 4/5 full scale.	SCS— GROUP 1 MN A MN B (MDC-25)	D-C main buses A and B		In backup SCS rate mode, the SCS rate electronics receive the sum of the SELF TEST and BMAG inputs. Therefore rate deflection will be 4/5 full scale (fixed) plus deflection caused by the analog of the rate signal, if any. SELF TEST is used each time the FDAI is activated.
	OFF	Removes test signal from rate indicators and permits normal operation of FDAI.				
	L/V AOA/SPS P <sub>C</sub> switch  L/V AOA  SPS P <sub>C</sub>  L/V AOA/SPS P <sub>C</sub> indicator	Connects output of Q-ball to L/V AOA/SPS P <sub>C</sub> indicator.  Connects output of SPS engine combustion chamber pressure sensor to L/V AOA/SPS P <sub>C</sub> indicator.  Time-shared indicator with input determined by position of L/V AOA/SPS P <sub>C</sub> switch.  a. L/V AOA input: the indicator displays a percentage of $\Delta P$ measured by the Q-ball which is a function of pitch and yaw.	None	N/A	None	Two-position toggle switch which enables the crew to select applicable input to L/V AOA/SPS P <sub>C</sub> indicator. The switch is placed in the L/V AOA position prior to lift-off, and in the SPS P <sub>C</sub> position at approximately 1 minute and 40 seconds after lift-off.  Indicator range: 0 to 150%.  Small changes in air pressures are sensed through four holes in the Q-ball. The indicator is monitored from 40 seconds to approximately one minute and 40 seconds after lift-off. It is red-lined at approximately 100 percent for the L/V AOA function. A decision for manual abort will be made when the indicator pointer reaches the red line and a movement is also noted on the FDAI.

MAIN DISPLAY CONSOLE—PANELS 2 AND 3

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CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-3 (Cont)		b. SPS P <sub>c</sub> input: the indicator displays SPS engine combustion chamber pressure during SPS thrusting as percentage of reference pressure value.	INSTRUMENTS-ESS MN A MN B (MDC-22)	D-C voltage from signal conditioner	SP0661P (Combustion chamber pressure sensor)	Reference pressure value for SPS P <sub>c</sub> input is 100 psia (nominal). Normal thrusting readout is 100 percent. Scale is graduated in % increments.
	MASTER ALARM switch-light	Red light illuminates to alert crewman in LH couch of a malfunction or out-of-tolerance condition. This is indicated by illumination of applicable system status lights on MDC-10 or -11.	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	CS0150X (Master caution-warning on)	MASTER ALARM lights on MDC-3, -18, and LEB-103 are simultaneously illuminated and an audio alarm tone is sent to each headset.  The C/W switch (MDC-13) is set to BOOST during the ascent phase only, preventing this MASTER ALARM switchlight from illuminating in order to avoid confusion with the adjacent red ABORT light. The switch-light loses its reset function during this time.  The MASTER ALARM switch-light contains an integral pushbutton switch. Pressing the switch-light will reset the master alarm circuit, extinguishing the MASTER ALARM lights and shutting off the audio alarm.
	ABORT light	Illuminates red to indicate that an abort has been requested by the range safety officer or ground control.	EDS-1, 3 BAT A BAT B (MDC-25)	Battery buses A and B when the EDS POWER switch is ON (MDC-24)	BX0080X (EDS abort request A)	The light serves to alert the crew of an emergency situation where an abort is required immediately. The light is a backup to voice communications from ground control. Redundant bulbs are controlled by redundant commands through the UDL real-time command system.
	SPS switches  GIMBAL MOTORS group  PITCH 1, PITCH 2, YAW 1, YAW 2 switches  START	Four operationally identical switches.  Energizes motor switch in applicable overcurrent relay which, in turn, applies +28 vdc to the applicable gimbal actuator drive motor.	SPS- GIMBAL MOTOR CONTROL 1 PITCH BAT A PITCH 2 BAT B 1 YAW BAT A YAW 2 BAT B (MDC-25)	Battery buses A and B	None	Three-position toggle switch with upper (START) position spring-loaded to return switch to center (ON) position when released. PITCH 1 and YAW 1 switches control gimbal actuator primary drive motors. PITCH 2 and YAW 2 switches control gimbal actuator secondary drive motors.  START position provides gimbal motor starting capability.

MAIN DISPLAY CONSOLE—PANEL 3



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## CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-3 (Cont)	ON	Applies +28 vdc to over-under-current sensing circuitry in applicable overcurrent relay.	SPS - GIMBAL MOTOR CONTROL	Battery buses A and B	None	ON position provides for over or undercurrent sensing (under 6 amps or over 40 amps nominal). During primary channel operation an over or undercurrent will automatically cause power to be removed from the primary drive motor, clutch commands switched to the secondary channel, and applicable GMBL DR FAIL status indicator to illuminate (MDC-11). During secondary operation, pitch 2 motor circuit is protected by CB 1 and yaw 2 motor circuit is protected by CB 2. CB 1 and CB 2 are 70 amp circuit breakers located in the S/M. No status indicators are provided for the secondary control circuits.
	OFF	Energizes motor switch in applicable overcurrent relay which removes +28 vdc from the current sensing circuitry and gimbal actuator drive motor.	1 PITCH BAT A PITCH 2 BAT B 1 YAW BAT A YAW 2 BAT B (MDC-25)			
	INJECT PRE-VALVES group A (B) switch	Two operationally identical switches. Each switch controls the pneumatic (GN <sub>2</sub> ) pressurization of the SPS engine valve-actuators within their respective half of a series/parallel propellant feed line configuration to the engine combustion chamber.	SPS-He VALVE MN A MN B (MDC-25)	D-C main buses A and B		During ascent, when GIMBAL MOTORS switches (4) are OFF, engine positioning is maintained by application of a quiescent current (60 +10, -5 ma) to the electromagnets of the extend and retract clutches when TVC 1 and 2 POWER switches (MDC 24) are on.
	ON	Applies +28 vdc to SPS engine system A pilot pre-valve solenoid.				
	OFF	Removes +28 vdc from SPS engine system A pilot pre-valve solenoid.				Two-position toggle switch which must be in ON position (i.e., solenoid is actuated) before automatic or manual SPS engine valve-actuator control of the main propellant valves can be initiated.

MAIN DISPLAY CONSOLE - PANEL 3

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CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-4	Flight director attitude indicator	Displays S/C total attitude, attitude errors, and angular rates.	SCS—GROUP 1 AC 1 GROUP 1 AC 2 AC 2 (MDC-25)	A-C bus No. 1 or No. 2 (via SCS display/ AGAA ECA)		Total attitude indicator calibration Pitch 0° - 360° (ball longitude) Yaw 270° - 0° - 90° (ball latitude) Roll 0° - 360° (bezel ring)
	Total attitude indication	S/C inertial attitude is displayed by orientation of the 3-axis attitude ball, with readouts as follows: a. Roll attitude is read from the ball-driven movable index (roll bug) referenced to the calibrated bezel ring around the ball, with respect to S/C navigation axes only. b. Pitch and yaw are read directly from the calibrated surface of the ball, with respect to either the S/C body axes index or the navigation axes index. Two 30° red circular areas on the ball surface denote attitude regions in which G&N IMU gimbal lock or excessive SCS AGCU error can occur.				Total attitude indicator direction of positive (+) rotation  Axis of rotation (other two axes fixed at 0°) Ball Rotation pitch — up yaw — right roll — right from top to bottom from right to left counterclockwise  Total attitude indication follows attitude deviations only in the following situations: a. When G&N system supplies inputs b. When CSS + translation control CW + .05g + (ATTITUDE IMPULSE-ENABLE) + (SCS attitude mode) + (pitch disabled + yaw disabled + both roll disabled) (BUR in any axis)'. (MTVC)'. (FDAI align)'.
	Attitude error indication	S/C attitude errors are displayed by three fly-to-type needles mounted on the bezel ring around the attitude ball, with the top, right, and bottom needles corresponding to roll, pitch, and yaw, respectively. The readouts denote one of the following: a. Difference between present S/C attitude and the S/C reference attitude stored in either the G&N ICDUs or the SCS AGCU. The readouts are always referenced to S/C body axes, except during G&N-controlled				Attitude error indicator calibration (full-scale deflection)  Modes Roll Pitch Yaw Monitor (G&N) ±25° ±15° ±15° G&N entry ±25° ±5° ±5° SCS entry All other modes ±5° ±5° ±5°

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MDC-4 (Cont)	Angular rate indication	<p>entry when the roll error needle is referenced to the S/C navigation axis. The pitch and yaw error needles will be zero after 0.05 g switching in a G&amp;N entry mode, and there will be no attitude error displayed after 0.05 g in an SCS entry mode.</p> <p>b. Difference between the present S/C reference attitude stored in the SCS AGCU and a desired attitude dialed into the attitude set/gimbal position display, with the ATTITUDE SET function engaged. Dialed in and stored attitudes are referenced to S/C navigation axes, with the difference angles inverted to body axes for display by the error needles.</p> <p>S/C angular velocities are displayed by three fly-to-type indicators mounted above, to the right of, and below the attitude ball, corresponding to roll, pitch, and yaw, respectively. The readouts are always referenced to S/C body axes except during atmospheric entry (after 0.05 g) when the yaw rate indicator is referenced to the S/C stability axis. Inputs to the indicators are supplied by either the SCS rate gyros (normal) or the SCS BMAGs (backup).</p>	SCS- GROUP 1 AC 1 GROUP 1 AC 2 (MDC-25)	A-C bus No. 1 or No. 2 (via SCS display/ AGAA ECA		<table><tr><td colspan="2">Attitude error indicator deflection for positive (+) rotational input commands</td></tr><tr><td>Axis of Rotation (positive command)</td><td>Indicator Deflection from Zero (center)</td></tr><tr><td>roll</td><td>left</td></tr><tr><td>pitch</td><td>up</td></tr><tr><td>yaw</td><td>left</td></tr></table> <table><tr><td colspan="4">Angular rate indicator calibration (full-scale deflection)</td></tr><tr><td>Modes</td><td>Roll</td><td>Pitch</td><td>Yaw</td></tr><tr><td>Monitor (G&amp;N)</td><td><math>\pm 25^\circ/\text{sec}</math></td><td><math>\pm 5^\circ/\text{sec}</math></td><td><math>\pm 5^\circ/\text{sec}</math></td></tr><tr><td>G&amp;N entry SCS entry</td><td></td><td></td><td></td></tr><tr><td>G&amp;N delta V</td><td><math>\pm 5^\circ/\text{sec}</math></td><td><math>\pm 5^\circ/\text{sec}</math></td><td><math>\pm 5^\circ/\text{sec}</math></td></tr><tr><td>SCS delta V</td><td></td><td></td><td></td></tr><tr><td>G&amp;N att cont</td><td><math>\pm 1^\circ/\text{sec}</math></td><td><math>\pm 1^\circ/\text{sec}</math></td><td><math>\pm 1^\circ/\text{sec}</math></td></tr><tr><td>SCS att cont</td><td></td><td></td><td></td></tr><tr><td>SCS lcl vert</td><td></td><td></td><td></td></tr><tr><td colspan="4">Angular rate indicator deflection for positive (+) rotational input commands</td></tr><tr><td>Axis of Rotation (positive command)</td><td colspan="2">Indicator Deflection from Zero (center)</td><td></td></tr><tr><td>roll</td><td colspan="2">left</td><td></td></tr><tr><td>pitch</td><td colspan="2">up</td><td></td></tr><tr><td>yaw</td><td colspan="2">left</td><td></td></tr></table>	Attitude error indicator deflection for positive (+) rotational input commands		Axis of Rotation (positive command)	Indicator Deflection from Zero (center)	roll	left	pitch	up	yaw	left	Angular rate indicator calibration (full-scale deflection)				Modes	Roll	Pitch	Yaw	Monitor (G&N)	$\pm 25^\circ/\text{sec}$	$\pm 5^\circ/\text{sec}$	$\pm 5^\circ/\text{sec}$	G&N entry SCS entry				G&N delta V	$\pm 5^\circ/\text{sec}$	$\pm 5^\circ/\text{sec}$	$\pm 5^\circ/\text{sec}$	SCS delta V				G&N att cont	$\pm 1^\circ/\text{sec}$	$\pm 1^\circ/\text{sec}$	$\pm 1^\circ/\text{sec}$	SCS att cont				SCS lcl vert				Angular rate indicator deflection for positive (+) rotational input commands				Axis of Rotation (positive command)	Indicator Deflection from Zero (center)			roll	left			pitch	up			yaw	left		
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MDC-5	Digital event timer	The event timer provides the crew with a means of monitoring and timing events. Indications from 00 minutes and 00 seconds (00-00) to 59 minutes and 59 seconds (59-59) are obtainable in a countup or countdown mode. In a countup mode, when 59-59 is recorded, the counter will proceed to 00-00 and continue to count up. In a countdown mode, continuous counting is also available.	EVENT TIMER MN A MN B (MDC-25)	D-C main buses A and B	None	The event timer is a reference system only and is automatically reset to zero when an abort is automatically or manually initiated.  The event timer starts automatically when lift-off occurs.
	L/V RATE light	Illuminates red to indicate that the permissible angular rates in any of pitch, roll, or yaw axes have been exceeded. Rates in excess of 20 degrees/seconds in roll and 5 degrees/second in pitch or yaw illuminate the rate light.	EDS-1, 3 BAT A BAT B (MDC-25)	Battery buses A and B when the EDS POWER switch (MDC-24) is ON.	BS0020X (Launch vehicle rate excessive A)	When used in conjunction with the angle-of-attack display and the attitude error reading of the FDAL, will indicate the necessity for manual abort initiation. The light also illuminates when an auto abort is initiated because of excessive rates.
	L/V GUID light	Illuminates red to indicate platform failure in the L/V guidance system (loss of attitude control).			BS0016X (Launch vehicle guidance fail A)	
	L/V ENGINES lights					All engine lights are yellow.  The lights are used to indicate staging and the necessity for initiating a manual abort when two S-IB engines are operating below 90 percent of thrust. When enabled in the auto abort mode, an auto abort will be initiated with two engines below 90 percent of thrust.
	Light No. 1	Illuminates to indicate S-IB or S-IVB engine No. 1 operating below 90 percent of total thrust capability.			BS0030X (Engine No. 1 out A)	
	Light No. 2	Illuminates to indicate S-IB engine No. 2 operating below 90 percent of total thrust capability.			BS0032X (Engine No. 2 out A)	
	Light No. 3	Illuminates to indicate S-IB engine No. 3 operating below 90 percent of total thrust capability.			BS0034X (Engine No. 3 out A)	
	Light No. 4	Illuminates to indicate S-IB engine No. 4 operating below 90 percent of total thrust capability.			BS0036X (Engine No. 3 out A)	

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MDC-5 (Cont)	Light No. 5	Illuminates to indicate S-IB engine No. 5 operating below 90 percent of total thrust capability.	EDS-1, 3 BAT A BAT B (MDC-25)	Battery buses A and B when the EDS POWER switch (MDC-24) is ON.	BS0038X (Engine No. 5 out A)	The LIFT OFF/NO AUTO ABORT switch/light combination should be pressed if the LIFT OFF light does not illuminate at lift off. (Refer to malfunction procedures.)
	Light No. 6	Illuminates to indicate S-IB engine No. 6 operating below 90 percent of total thrust capability.			BS0040X (Engine No. 6 out A)	
	Light No. 7	Illuminates to indicate S-IB engine No. 7 operating below 90 percent of total thrust capability.			BS0042X (Engine No. 7 out A)	
	Light No. 8	Illuminates to indicate S-IB engine No. 8 operating below 90 percent of total thrust capability.			BS0044X (Engine No. 8 out A)	
	LIFT-OFF and NO AUTO ABORT lights	White light illuminates at lift-off.			BS0060X BS0061X (Lift-off signal A & B)	
	NO AUTO ABORT light	Switch-light will illuminate red at lift-off if either of the LV-EDS auto abort systems has not been automatically enabled.			None	The relay controlling the white light is reset 5 seconds after lift-off by a timer in the L/V instrumentation unit.
	LES MOTOR FIRE switch	a. Backup switch to fire the launch escape motor. b. Backup switch to jettison the LES tower in the event the jettison motor failed to ignite	MASTER EVENTS SEQ CONT - A ARM B BAT A BAT B (MDC-22)	Battery buses A and B	CD0101X LE/Pc motor fire initiate A CD0102X LE/Pc motor fire initiate B	The astronaut will press the switch-light which will electrically enable the LV-EDS automatic abort system. If the light still does not go out, it indicates that one or both of the dual redundant EDS systems is not enabled. In this event, the crew must be prepared to initiate a manual abort, if necessary.  The LES motor is normally (automatically) fired approximately 0.1 second by the MESC following abort initiation. It may be used for a back-up for the jettison motor only after normal means of TWR jettison has failed. This is assuming that the TWR separation nuts are fractured.

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MDC-5 (Cont)	CANARD DEPLOY switch	Backup switch to deploy the canard when it does not deploy automatically during an abort.	MASTER EVENTS SEQ CONT- A ARM B BAT A BAT B (MDC-22)	Battery buses A and B	CD0120X CD0121X Canard deploy A and B	Push-type switch. The canard will normally (automatically) deploy 11 seconds after a LES abort initiation.
	ADAP SEP switch	a. Switch for normal CSM/S-IVB separation after the ascent phase of the mission. (Refer to adapter separation mechanism in section 2.) b. Backup switch for CSM/S-IVB separation if it does not separate automatically during an SPS abort. (Refer to SPS abort procedures.)			CD0125X Adapter/ SM separate initiate A CD0126X Adapter/ SM separate initiate B	Push-type switch to separate the adapter when an SPS abort cannot be initiated with the commanders translational control. SPS ullage and firing would be manual functions.
	APEX COVER JETT switch	Backup switch to jettison the C/M apex cover.	ELS A- BAT A- FLOAT BAG 3 ELS B- BAT B (MDC-25)		CD0230X Forward heat shield jettison A CD0231X Forward heat shield jettison B	Push-type switch to jettison the C/M apex cover if the automatic system fails during an abort or earth landing after a normal mission.
	DROGUE DEPLOY switch	Backup switch to deploy the drogue parachutes.			CE0001X Drogue deploy relay close A CE0002X Drogue deploy relay close B	Push-type switch. The drogue parachutes will normally (automatically) deploy 2 seconds after the 24,000 feet baro switch closes.
	MAIN DEPLOY switch	Backup switch to deploy the main parachutes.			CE0003X Main para- chute deploy -drogue release relay A CE0004X Main para- chute deploy -drogue release relay B	Push-type switch. The main parachutes will normally (automatically) deploy when the 10,000 feet baro switch closes during descent. The switch is also used to initiate manual deployment of the main parachutes during aborts initiated prior to 61 seconds after lift-off.

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MDC-5 (Cont)	Backup switches lock control  LOCK  UNLOCK	Locks the backup switches to prevent inadvertent operation.  Unlocks and enables the backup switches to be pushed manually.	N/A	N/A	None	
MDC-6	ATTITUDE SET group  ROLL, PITCH, YAW thumbwheels and indicators	Enables manual insertion of a desired attitude reference into the SCS, either for AGCU alignment or for a commanded S/C attitude maneuver reference during SCS flight modes.  Enable manual selection and display of desired roll, pitch, and yaw attitude settings referenced to S/C navigation axes.	SCS— GROUP 1 AC 1 GROUP 1 AC 2 (MDC-25)	A-C bus No. 1 or No. 2	None	Yaw thumbwheel is marked with a stripe, denoting yaw angles of 75° and 285°, as a caution against dialing in settings at which G&N IMU gimbal lock or excessive SCS AGCU error can occur.  Indicators provide digital type displays.
	FDAI ALIGN switch	a. Couples manually selected (dialed in) attitude settings into the SCS for alignment of the present S/C reference attitude stored in the AGCU to the desired reference attitude. b. Decouples normal SCS BMAG inputs to the AGCU and the BMAGS are free gyros until the switch is released. c. Aligns the FDAI attitude ball to the dialed-in attitude, referenced to S/C navigation axes, in SCS flight modes only.	SCS— GROUP 1 MN A MN B (MDC-25)	D-C main bus A or B		Momentary-contact pushbutton switch which must be held engaged until alignment is completed.  SCS AGCU alignment slew rates  roll — 20°/sec pitch — 5°/sec yaw — 5°/sec  Perform the FDAI/AGCU align function.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-6 (Cont)	ATT SET switch On (up)	a. Couples the attitude difference angles to the FDAI attitude error indicators, referenced to S/C body axes. b. Decouples normal SCS BMAG inputs to the FDAI attitude error indicators. (BMAGs continue to operate normally otherwise.)  Inhibits the attitude set function.	SCS— GROUP 1 MN A MN B (MDC-25)	D-C main bus A or B	None	The attitude set function which enables S/C maneuver to a desired (dialed in) attitude is applicable to SCS flight modes only. The desired attitude is achieved by flying out the attitude error needles, using the rotation control.
	OFF					
	GIMBAL POSITION group  YAW, PITCH indicators  YAW, PITCH thumbwheels	Provides display and manual control of gimbaled SPS engine thrust axis orientation with respect to S/C body axes.  Provide display of engine gimbal position readouts with respect to S/C yaw and pitch (body) axes, respectively.  Provide manual yaw and pitch input commands to respective engine gimbal position servos for alignment of SPS engine thrust axis through S/C CG, prior to SPS thrusting.  Thumbwheel displacement in a positive direction will provide a relative positive gimbal position indicator display indicating nozzle positioning for a positive axis displacement when thrust is initiated.	SCS GROUP 1 AC 1 & AC 2 GROUP 2 AC 1 & AC 2 (MDC-25)	A-C bus No. 1 or No. 2  (via yaw and pitch ECAs)  (via display/AGAA ECA)	CH3135V (pitch GPI amp demod out)  None	Yaw indicator and thumbwheel are calibrated in 0.5° increments from -3° to +13°. Center reading of +4° corresponds to yaw gimbal position null, due to engine offset for S/C CG.  Pitch indicator and thumbwheel are calibrated in 0.5° increments from -9° to +9°. Center reading of 0° corresponds to pitch gimbal position null.  Trimming of gimbal positions by use of the thumbwheels is possible when performing MTV. Group 2 circuit provides power to MTV circuits.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-7	DIRECT ULLAGE switch	Provides backup capability for initiating ullage (+X translation) prior to SPS burns.  a. Energizes injector valve direct coils of four +X SM RCS engines. b. Disengages automatic attitude hold capability in pitch and yaw axes.	SCS - DIRECT CONT MN A MN B (MDC-25)	D-C main bus A or B	None	Momentary-contact pushbutton switch which must be held engaged until ullage is completed.  Translation control provides normal capability for initiating ullage.
	THRUST ON switch light	a. Switch actuation applies manual SPS engine thrust-on logic command to SCS electronics which energizes coils of SPS engine helium isolation valves (if SPS He switch on MDC-20 is in AUTO position) and pilot control valves.  b. Switch face illumination indicates application of SPS engine thrust-on signal from G&N system or THRUST ON switch to SCS electronics. Light is extinguished when SPS engine thrust-off signal from G&N system, $\Delta V$ REMAINING counter, or flight combustion stability monitor is detected in SCS electronics.	SCS - GROUP I MN A MN B (MDC-25)		CH4320X (SPS solenoid control valve energized)   CH4321X (SPS solenoid control valve energized)	Pushbutton momentary-contact-type switch. Provides normal SPS engine ignition control in SCS $\Delta V$ mode, backup control in G&N $\Delta V$ mode.  FDAI BRIGHTNESS control must be on to provide switch face illumination.  Switch face does not indicate application of thrust on/off commands via the NORMAL/OFF/DIRECT ON switch (MDC-7).
	NORMAL/OFF/DIRECT ON switch  NORMAL  OFF	Enables circuit capability for energizing of SPS fuel and oxidizer control solenoids by either AGC or THRUST ON switch stimuli, providing all other logic is complied with.  Provides capability to remove power from the four SPS engine pilot control valve solenoids directly, thereby, terminating thrust.	SCS - DIRECT CONT MN A MN B (MDC-25)		None	Switch is a three-position lever-lock toggle switch. To set the switch in the NORMAL position or the DIRECT ON position, pull the lever out past the lever lock (shoulder stop) and move the lever up and down, respectively. The in-flight position of the switch is the OFF (center) position. DIRECT ON position provides capability of bypassing thrust on logic circuit and initiating SPS engine firing directly.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-7 (Cont)	DIRECT ON	Connects +28 vdc direct from circuit breaker to SPS pilot control valve solenoids.  Energizes SPS driver relays K1 and K2, which provide power application to helium isolation valves and PUGS.	SCS DIRECT CONT MN A MN B (MDC-25)	D-C main buses A or B	None	The DIRECT ON switch overrides FCSM.
	$\Delta V$ SET switch	Enables desired $\Delta V$ to be placed on $\Delta V$ REMAINING display.  Enables increase of $\Delta V$ REMAINING display at rate of 64 digits per sec.  Enables increase of $\Delta V$ REMAINING display at rate of 2 digits per sec.	SCS GROUP 1 AC 1 GROUP 1 AC 2 (MDC-25)	$\pm 15$ vdc from DISP/AGAA ECA		The $\Delta V$ set switch is a five-position switch with two + ( $\Delta V$ increase) positions, two - ( $\Delta V$ decrease) positions, and an OFF (center) position.
	Upper hardstop (uppermost position)  Upper softstop (upper middle position)  Center position  Lower softstop (lower middle position)  Lower hardstop (bottommost position)	Provides inhibit to $\Delta V$ counter after TVC #1 power switch is turned on until a xx ullage is initiated, except when open.  Enables decrease of $\Delta V$ REMAINING display at rate of 2 digits/per sec.  Enables decrease of $\Delta V$ REMAINING display at rate of 64 digits/per sec.				
	$\Delta V$ REMAINING indicator	Displays $\Delta V$ magnitude and/or $\Delta V$ REMAINING in feet per second.		DISP/AGAA ECA	CH3186V $\Delta V$ remaining	When the SPS engine is thrusting, the $\Delta V$ REMAINING indicator receives a signal from the SCS X-axis accelerometer, driving the indicator toward zero. The $\Delta V$ REMAINING display is activated when the TVC 1 POWER switch is set to either AC 1 or AC 2 position and the integrator circuit threshold of $5 \times 10^{-4}$ g has been attained while performing a +X (only) translation maneuver. Acceleration sensing will begin at ullage or +X RCS translation initiation. An indicating range from -1000 (99, 000) to 12, 999 feet/second (f/s) is provided at an accuracy of $\pm 1.5$ percent or 0.75 f/s, whichever is greater.

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MDC-7 (Cont)			SCS GROUP 1 AC 1 GROUP 2 AC 2 (MDC-25)	DISP /AGAA ECA	CH3816V ΔV remaining	When thrusting in SCS ΔV mode, thrust-off signal is terminated when ΔV REMAINING display reaches 00000. The thrust-off signal is inhibited by the AGC when operating in G&N ΔV mode. No inhibit is provided by the ΔV REMAINING display circuits when in the G&N ΔV mode.
MDC-8	DIRECT RCS switch  DIRECT RCS (up)  OFF	Provides capability for direct manual control of S/M or C/M-R S engines.  Applies d-c power to rotation control, enabling direct manual control of S/M or C/M-RCS engines.  Removes manual direct control capability of the S/M or C/M-RCS engines.	SCS DIRECT CONT MIN A MIN B (MDC-25)	D-C main buses A or B	None	DIRECT RCS position provides the crew with direct control of the S/M or C/M RCS engines for rotational maneuver commands. Direct control is achieved by positioning the rotation control to engage the direct switches for the desired axis change. Direct switches are engaged at $1 \pm 0.5$ degree from any hard stop. All SCS electronics are bypassed during this function.
	LIMIT CYCLE switch  LIMIT CYCLE  OFF	Provides manual capability to retain or inhibit SCS pseudo rate (limit cycling) during RCS engine operation.  Allows normal operation of SCS pseudo rate circuit, providing limit cycling of RCS engines during attitude control modes.  Prevents operation of SCS pseudo rate circuit in pitch, yaw, and roll ECAs.	None	None		The primary purpose of the LIMIT CYCLE switch is to provide the crew with the capability of manually inhibiting the pseudo rate circuit operation during maneuvering and the entry phase of the mission. For fuel conservation, the switch should be set to LIMIT CYCLE position when holding attitude with the S/M RCS. The LIMIT CYCLE position function is disabled when the breakout switches in the rotation control are actuated, or when manual translation is commanded.
	ATT DEADBAND switch  MAX	Enables selection of attitude deadband control sensitivity.  Selects maximum attitude deadband of $\pm 4.2^\circ$ .	SCS GROUP 1 MN A MN B (MDC-25)	D-C main buses A or B		This switch selects a deadband in SCS that prevents attitude correction signals from being applied to the RCS until the attitude error exceeds the selected deadband.

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MDC-8 (Cont)	MIN	Selects minimum deadband of $\pm 0.2^\circ$ .	SCS - GROUP 1 MN A MN B (MDC-25)	D-C main buses A or B	None	Minimum deadband is used only when tight attitude control is required; e.g., during navigational sightings and prior to and during $\Delta V$ maneuvers.  No power to this switch during SCS or G&N entry modes; therefore, minimum deadband cannot be selected during entry.
	RATE GYRO switches	Provide manual capability to place the roll, pitch, or yaw BMAG in the backup rate mode of operation.				These switches place any or all of the BMAGs in backup rate mode of operation so that they may be used in place of the rate gyros to provide spacecraft rate stabilization. In addition, with any one of the RATE GYRO switches in the BMAG position and any one of the following selected, the remaining two BMAGs will automatically assume the backup rate mode of operation: .05G ENTRY switch to .05G ENTRY position, monitor mode selected, G&N attitude control mode selected, minimum impulse attitude control mode engaged, G&N entry mode selected, either rotation control out of neutral position, SCS local vertical, or one SCS channel disabled while in SCS attitude control mode.
	ROLL	Allows normal BMAG and rate gyro operation.				
	NORMAL	Enables BMAG rate mode of operation removing rate gyro signal from rate indicators, etc.				
	BMAG					
	PITCH					
	NORMAL	Allows normal BMAG and rate gyro operation.				
	BMAG	Enables BMAG rate mode of operation, removing rate gyro signal from rate indicators, etc.				
	YAW					
	NORMAL	Allows normal BMAG and rate gyro operation.				
	BMAG	Enables BMAG rate mode of operation, removing rate gyro signal from rate indicators, etc.				When in an SCS mode, the attitude reference capability is lost when any one of the BMAGs is in backup rate mode. Attitude information is maintained if operating in a G&N mode.
	.05G ENTRY switch	Enables the SCS for atmospheric flight during entry and after 0.05g				.05G ENTRY switch is effective only when a G&N or SCS entry mode is selected.
	.05G ENTRY	a. Removes attitude error signals from pitch and yaw channels in G&N mode and pitch, yaw, and roll channels in SCS modes.				After .05G ENTRY position is selected, placing any one of the BMAGs in backup rate mode will automatically place all BMAGs in backup rate mode configuration. This

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-8 (Cont)		<p>b. Increases the rate deadband from 0.2° per sec to 2° per sec.</p> <p>c. Energizes a circuit which couples a component of the roll rate signal into the yaw channel.</p> <p>Allows normal system operation.</p>	SCS— GROUP 1 MN A MN B (MDC-25)	D-C main buses A or B	None	<p>results in loss of FDAI total attitude display, otherwise, total attitude display is provided.</p> <p>During entry the S/C is maneuvered about the stability roll axis rather than the body roll axis. Consequently the yaw rate gyro generates an undesirable rate signal. By coupling a component of the roll signal into the yaw channel, the undesirable signal is cancelled.</p>
	LCL VERT switch	Enables SCS for local vertical mode operation.			CH1103X (SCS local vertical mode control)	<p>The local vertical mode maintains the S/C attitude with respect to the earth's local vertical.</p> <p>With local vertical mode engaged, an orbit rate signal equivalent to pitch rate of approximately 4.1° per minute is applied to the pitch BMAG torque motor. This figure is for a 100 NM earth orbit. FDAI total attitude is referenced to local vertical. Attitude error values represent deviation from selected local vertical attitude.</p>
	LCL VERT (up)	Selects SCS local vertical mode when used in conjunction with G&N/SCS switch and ATTITUDE/MONITOR/ENTRY switch.				<p>If the S/C is maneuvered after local vertical mode is selected, the 4.1° per minute orbit rate signal previously applied only to the pitch gyro will be applied to all three gyros. This is accomplished by summing and resolving the new stepper motor position outputs with the orbital rate signal in the nav-to-body transformation circuits.</p>
	OFF	Disengages local vertical mode.				<p>If the S/C is maneuvered after local vertical mode is selected, the 4.1° per minute orbit rate signal previously applied only to the pitch gyro will be applied to all three gyros. This is accomplished by summing and resolving the new stepper motor position outputs with the orbital rate signal in the nav-to-body transformation circuits.</p>
	ΔV switch	Enables SCS for G&N or SCS ΔV mode operation or MTVC.			CH0100X (G&N ΔV mode)	<p>This switch works in conjunction with the G&amp;N/SCS switch and the ATTITUDE/MONITOR/ENTRY switch.</p>
	ΔV (up)	Applies a signal to the SCS electronics enabling the system for ΔV modes of operation and also enables manual thrust vector control (MTVC), of the translation control SW switch is closed.			CH1100X (5c ΔV mode)	<p>MTVC is actuated only when the ΔV switch is in the ΔV position and when the translation control is rotated CW. MTVC is independent of G&amp;N/SCS switch.</p>
					CH1104X (MTVC mode)	<p>In the ΔV position, DC power is applied to the FCSCM-G&amp;N and FCSCM-SCS switches (MDC-2).</p>

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks																					
MDC-8 (Cont)	OFF	Inhibits $\Delta V$ and MTVC modes of operation and permits operation of the SCS in other modes.	SCS— GROUP 1 MN A MN B (MDC-25)	D-C main buses A or B	CH0101X (G&N attitude control mode control)  CH1101X (SCS attitude control mode)	The G&N/SCS switch works in conjunction with the other flight control mode switches. When the switch is positioned to G&N or SCS position, $\Delta V$ maneuvers and attitude control of the S/C is accomplished by the selected system.																					
	G&N/SCS switch	Selects either G&N or SCS control of the various flight control modes.																									
	G&N (up)	Enables G&N control for the following modes: attitude control, entry, and $\Delta V$ maneuvers.																									
	SCS	Enables SCS control for the following modes: attitude control, monitor, local vertical, entry, and $\Delta V$ maneuvers.																									
	ATTITUDE/MONITOR/ENTRY switch	Selects one of the following basic flight control modes: attitude control, monitor, or entry.																									
	ATTITUDE	Enables G&N or SCS attitude control mode. (Refer to Remarks.)	SCS— A&C ROLL MN A MN B and GROUP 1 MN A and MN B (MDC-25)			CH0103X (Monitor mode control)  CH0102X (G&N entry mode control)  CH1102X (SCS entry mode)	The ATTITUDE/MONITOR/ENTRY switch works in conjunction with the G&N/SCS switch, the $\Delta V$ switch, and the LCL VERT switch to enable crew selection of the various flight control modes. For details of the switch positions required to select the flight control modes, refer to Normal/Backup Procedures. In the attitude or monitor modes, the rate deadband for all axes is 0.2°/sec. The rate deadband for all axes in entry mode is 2.0°/sec. This applies to either entry mode: SCS or G&N.  Monitor position selects the G&N monitor mode independent of other mode switches.																				
	MONITOR	Enables monitor mode. (Refer to Remarks.)																									
	ENTRY	Enables G&N or SCS entry mode. (Refer to Remarks.)																									
	SCS CHANNEL switches	Provides capability to manually deactivate the RCS engines.	SCS— A&C ROLL MN A MN B and GROUP 1 MN A and MN B (MDC-25)			None	These switches are used to disable the RCS engines in the event of a malfunction or whenever it may be operationally desirable; e.g., S/C three-axis free drift for purposes of propellant conservation.  Direct control of the RCS is available, using the DIRECT MODE switch and the rotation control.  Maneuver function - engine activation.																				
	A&C ROLL	Applies +28 vdc to the normal injector valve solenoids and the driver solenoid amplifier, allowing normal RCS engine operation.																									
	On (up)	Removes +28 vdc from the normal injector valve solenoids and the driver solenoid amplifier. Inhibits normal manual rotation control capability and SCS automatic control of RCS engine operation.																									
	OFF																										
						<table><thead><tr><th>Switch</th><th>Function</th><th>S/M RCS Engine</th></tr></thead><tbody><tr><td>A&amp;C ROLL</td><td>Roll right</td><td>A13, C15</td></tr><tr><td>A&amp;C ROLL</td><td>Roll left</td><td>A16, C14</td></tr><tr><td>B&amp;D ROLL</td><td>Roll right</td><td>B9, D11</td></tr><tr><td>B&amp;D ROLL</td><td>Roll left</td><td>B12, D10</td></tr><tr><td>PITCH</td><td>Pitch up</td><td>A3, C1</td></tr><tr><td>PITCH</td><td>Pitch down</td><td>A2, C4</td></tr></tbody></table>	Switch	Function	S/M RCS Engine	A&C ROLL	Roll right	A13, C15	A&C ROLL	Roll left	A16, C14	B&D ROLL	Roll right	B9, D11	B&D ROLL	Roll left	B12, D10	PITCH	Pitch up	A3, C1	PITCH	Pitch down	A2, C4
Switch	Function	S/M RCS Engine																									
A&C ROLL	Roll right	A13, C15																									
A&C ROLL	Roll left	A16, C14																									
B&D ROLL	Roll right	B9, D11																									
B&D ROLL	Roll left	B12, D10																									
PITCH	Pitch up	A3, C1																									
PITCH	Pitch down	A2, C4																									

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks		
						Switch	Function	S/M RCS Engine B7, D5 B6, D8
MDC-8 (Cont)	B&D ROLL  On (up)	Applies +28 vdc to the normal injector valve solenoids and solenoid driver electronics, allowing normal RCS engine operation.  Removes +28 vdc from the normal injector valve solenoids and the driver solenoid amplifier. Inhibits normal manual rotation control capability and SCS automatic control of RCS engine operation.	SCS- B&D ROLL MN A MN B and GROUP 1 MN A and MN B (MDC-25)	D-C main buses A or B	None	YAW	Yaw right	C/M RCS Engine A9, B11 A12, B10 A1, B3 A2, B4 A5, B7 A8, B6
						YAW	Yaw left	
	PITCH  On (up)	Applies +28 vdc to the normal injector valve solenoids and solenoid driver electronics, allowing normal RCS engine operation.  Removes +28 vdc from the normal injector valve solenoids and the driver solenoid amplifier. Inhibits normal manual rotation control capability and SCS automatic control of RCS engine operation.	SCS- PITCH MN A MN B and GROUP 1 MN A and MN B (MDC-25)			B&D ROLL B&D ROLL PITCH PITCH YAW YAW	Roll right Roll left Pitch up Pitch down Yaw right Yaw left	
	OFF							AC roll switch is applicable to S/M-RCS engines only and provides no function after GM/SM separation.
	YAW  On (up)	Applies +28 vdc to the normal injector valve solenoids and solenoid driver electronics, allowing normal RCS engine operation.  Removes +28 vdc from the normal injector valve solenoids and the driver solenoid amplifier. Inhibits normal manual rotation control capability and SCS automatic control of RCS engine operation.	SCS- MN A MN B and GROUP 1 MN A and MN B (MDC-25)					These switches are used to disable the RCS engines in the event of a malfunction or whenever it may be operationally desirable; e.g., S/C free drift for purposes of propellant conservation.
	OFF							Direct control of the RCS is available, using the DIRECT RCS switch and the rotation control.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-8 (Cont)	ELS LOGIC switch					
	Up	Connects 28 vdc to the ELS logic arm circuitry. The circuitry is automatically armed during an LES abort if the MAIN DEPLOY-AUTO/MAN switch (MDC-16) is in the AUTO position.	ELS - A BAT A - FLOAT BAG 3 ELS - B BAT B (MDC-25)	Battery buses A and B	None	The logic switch is positioned up during entry or after an SPS abort to arm the ELS logic circuitry. This circuitry is armed automatically on LES aborts. The ELS is controlled by baroswitch closure and time-delay relays after being armed.
	OFF	Disconnects 28 vdc from ELS logic circuitry.				The switch should never be positioned up under 42,000 feet except as backup during an LES abort. The LES tower, apex cover and parachutes might be jettisoned.
	DIGITAL EVENT TIMER switches					
	RESET/UP/DOWN switch		EVENT TIMER MN A MN B (MDC-25)	D-C main buses A and B		
	RESET	Reset the event timer (MDC-5) to zero.				The event timer is automatically reset to zero and starts counting up when an abort is automatically or manually initiated. The switch is momentary on towards the RESET position and maintain on in the other two positions.
	UP	Completes circuitry for the event timer to time up.				
	DOWN	Completes circuitry for the event timer to time down.				
	START/STOP switch					
	START	Starts the event timer.				The event timer starts automatically when lift-off occurs. The switch is momentary on towards the START position and maintain on in the other two positions.
	Center	No function.				
	STOP	Stops the event timer.				
	MIN switch					
	TENS	Runs the MIN indicating drums in tens.				The control switches provide a means of running the event timer to any desired setting and are spring-loaded to the center position. The indicating drums can be run up or down, depending on the position of the RESET/UP/DOWN switch.
	Center	No function.				
	UNITS	Runs the second MIN indicating drum in units.				

MAIN DISPLAY CONSOLE—PANEL 8



## CONTROLS AND DISPLAYS

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-8 (Cont)	DUMP switch  On (up)	Removes power from C/M RCS HTRS switch (RHFE-200). Enabled by LOGIC switch.  Energizes relays required to activate C/M-RCS propellant dump-burn operation through 10 engine-injector valves.	RCS - C/M-S/M TRANSFER MN A MN B (MDC-25)	D-C main buses A and B	None	Guarded two-position toggle switch (activates explosive-operated valves). During normal entry, switch is placed to DUMP (up) position when main parachute line stretch is felt. Remaining propellants are then burned off through 10 of the 12 RCS engines.
	OFF	De-energizes relays.				The two positive pitch engines do not permit fuel dump or burn.  DUMP switch will not be utilized during pad aborts or low altitude aborts, fuel only is retained on-board and the CM will land with fuel tanks full, but depressurized.
	PURGE switch  On (up)	Energizes relays required to activate the following: a. C/M RCS propellant system purge operation b. ECS gas chromatograph helium dump operation.				Two-position toggle switch. Switch manually set to the up position after C/M propellant supply has been depleted (approximately 88 seconds, after activation of FUEL DUMP/BURN switch, for 10-engine burn and 132 seconds for 5-engine burn). All four propellant tank lines are purged with helium to ensure that no hypergolic propellant remains in the propellant distribution or engine systems. (Purge operation approximately 10 seconds.) The LOGIC and DUMP switches must both be in the up position before the purge operation can be initiated.
	OFF	De-energizes relays.				Switch will not be utilized during abort operations if fuel is retained on-board.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-9	Coaxial bracket MDC		N/A	None	None	<p>Change is implemented by manually disconnecting RF coaxial connector from VHF recovery antenna No. 1 or No. 2 connector and reconnecting to coaxial connector on cable to GF AE survival transceiver.</p> <p>Permits two-way AM voice communications or beacon transmission on GF AE survival transceiver (243.0 mc) over antenna No. 1 and VHF-AM two-way voice communication (296.8) on antenna No. 2.</p> <p>Permits two-way AM voice communications or beacon transmission on GF AE survival transceiver (243.0 mc) over antenna No. 2 and VHF recovery beacon transmission (243.0 mc) on antenna No. 2.</p>
	Normal installation	Connects VHF recovery antenna No. 1 to the VHF recovery beacon and VHF recovery antenna No. 2 to the VHF/AM transmitter-receiver.				
	Survival transceiver installation	Connects either recovery antenna No. 1 or No. 2 to the GF AE survival transceiver.				
	Crossover installation	Connect GF AE survival transceiver to recovery antenna No. 1 (right connector).				
MDC-10	G&N system status lights	Connect GF AE survival transceiver to recovery antenna No. 2 (left connector).	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	<p>CG5002X (CDU fail)</p> <p>CG5001X (IMU fail)</p> <p>CG5006X (IMU temp light)</p> <p>CG5000X (PIPA fail)</p> <p>CG5005X (Error detect)</p> <p>CG5003X (Gimbal lock warning)</p>	<p>Yellow lights indicate failure or out-of-tolerance condition when illuminated.</p>
		Indicates a failure in one or more of the coupling display units.				
		Indicates a failure in the inertial measurement unit.				
	CDU FAIL	Indicates that the IMU temperature is out of tolerance, i.e., exceeds normal temperature by $\pm 4^{\circ}$ .				
	IMU FAIL	Indicates a failure in one or more of the PIP accelerometers.				
	IMU TEMP	Indicates an IMU, CDU, accelerometer and/or AGC error.				
	G&N ACCEL FAIL	Indicates a potential gimbal lock condition in the IMU (middle gimbal angle is greater than $\pm 60$ degrees with respect to the outer gimbal).				
	G&N ERROR					
	GMBL LOCK					

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-10 (Cont)	ACC PWR FAIL	Indicates a power failure in the Apollo guidance computer.	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	CG5030X (Computer power fail light)	
	SCS status light					
	AGAP TEMP	Illuminates when the temperature of any one of three BMAGs in the SCS attitude gyro accelerometer package varies from 170±2°F.			CH2030T (Combined attitude gyro temp)	When illuminated, the status light indicates an out-of-temperature condition in one or more of the three BMAGs. When light is out, BMAG outputs are usable.
	EPS status lights					
	H <sub>2</sub> PRESS	Indicates hydrogen tank pressure as follows: a. 220 psia or below b. 270 psia or above.			SF0039P (Press H <sub>2</sub> tank 1) SF0040P (Press H <sub>2</sub> tank 1)	Yellow lamp will illuminate if either or both H <sub>2</sub> tanks are above or below proper pressure limits. Pressure in H <sub>2</sub> tanks can be monitored by indicators on MDC-13.
	O <sub>2</sub> PRESS	Indicates oxygen tank pressure as follows: a. 800 psia or below b. 950 psia or above.			SF0037P (Press O <sub>2</sub> tank 1) SF0039 (Press O <sub>2</sub> tank 2)	Yellow lamp will illuminate if either or both O <sub>2</sub> tanks are above or below proper pressure limits. Pressure in O <sub>2</sub> tanks can be monitored by indicators on MDC-13.
	RCS status lights	A and B lights are identical in operation within their respective systems.  Indicates an underpressure condition in the fuel and oxidizer tanks of the respective system prior to system pressurization.  Indicates an over or underpressure condition (below 265 psia or above 325 psia) in the fuel and oxidizer tanks of the respective propellant system.			None	All lights are yellow. The RCS INDICATOR switch can be used in conjunction with the propellant indicating devices to isolate a malfunction to a specific temperature, or pressure, within a particular RCS package. A temperature transducer is located on the inner surface of each S/M-RCS quad. A pressure transducer is installed in the helium line of each S/M-RCS quad and each C/M-RCS system. When the status lights are out, the applicable system is operable.
	S/M RCS A, B, C, D	Indicates one of the following: a. Package temperature below 63°F or above 175°F (nominal)				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-10 (Cont)		b. Regulated helium pressure below 155 psia or above 215 psia (nominal).	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	None	
	SPS status light SPS ROUGH ECO	Indicates FCSM cut-off of SPS engine due to excessive engine vibration level.	CAUT/ WARN MN A MN B (MDC-25)			Yellow light. Delay time for cutoff is nominally 70±20 milliseconds at a vibration level of 180 g's peak-to-peak. Delay time will be 30 to 70 milliseconds at a vibration level of 360 g's peak-to-peak. Light will extinguish when FCSM circuitry is reset.
MDC-11	ECS status lights H <sub>2</sub> O ACCUM FAIL	Indicates when a minimum of three oxygen bubbles are detected in water expelled from H <sub>2</sub> O accumulators.	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	None	The yellow light illuminates in event of water accumulator diaphragm rupture. Oxygen will then enter the waste water network.  A sensor is placed in the accumulator water outlet line. Oxygen bubbles in the water are sensed as a change in voltage. When three positive pulse signals (corresponding to three bubbles) are received, a voltage divider is unbalanced, resulting in light illumination.
	GLYCOL TEMP LOW	Indicates when water-glycol from space radiator outlet decreases to -30°F.			CF0020T (Temp space radiator outlet)	The yellow light illuminates to indicate water-glycol is approaching the temperature where flow is reduced.  Continuous temperature is displayed by ECS RAD-OUTLET TEMP indicator (MDC-13).  Transducer is placed in line downstream of space radiator outlet in LHEB, and furnishes signal for light and indicator.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-11 (Cont)	CO <sub>2</sub> PP HI	Indicates when CO <sub>2</sub> partial pressure reaches 7.6 mm Hg.	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	CF0005P (Press CO <sub>2</sub> partial)	The yellow light illuminates at upper end of normal range. A CO <sub>2</sub> -odor absorber filter change is required only if the illumination of the light is not the result of temporarily increased crew activities.
	O <sub>2</sub> FLOW HI	Indicates when total ECS oxygen flow reaches 1 lb per hr.			None	Continuous partial pressure is displayed by PART PRESS - CO <sub>2</sub> indicator (MDC-13).
	SPS status lights					The red light illuminates at critical flow rate which, if continuous, indicates cabin leakage, oxygen subsystem leakage, or mismanagement of oxygen subsystem.
		PITCH GMBL DR. FAIL				Continuous O <sub>2</sub> flow is displayed by FLOW O <sub>2</sub> indicator (MDC-13).
		YAW GMBL DR FAIL				Yellow lights. Light indicator is a constant visual aid to assist in evaluating functional status of engine gimbal drive components.
		SPS PRESS				
						Yellow light. Two pressure transducers, one located in each (Ox and Fuel) regulated helium supply line, provide input to indicator. Continuous pressures are displayed by PRESSURE indicators on MDC-20.
	SPS WALL TEMP HI	Indicates wall temperature of SPS engine combustion chamber exceeds high operating temperature limit of 380°F.				Yellow light. Indicator input is provided by temperature sensor mounted in engine combustion chamber wall assembly.
	SPS PU SNR FAIL	Indicates one of the following: a. An unbalance in the remaining SPS propellants from the desired ratio (by weight) in excess of 300 lb or 90 percent of critical unbalance.				Yellow light is functional only during SPS engine firing or when TEST/AUTO/TEST switch (MDC-20) is in the TEST up or down position. Critical unbalance is that point at which the propellant utilization valve will no longer provide oxidizer adjustment.

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MDC-11 (Cont)		b. Discrepancy of 300 lbs between the primary and auxiliary sensing systems.	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	None	great enough to permit simultaneous propellant depletion.
	C&WS status light CAUT/WARN FAIL	Indicates when power supply voltage (positive or negative) is outside of the 11.7 to 13.9 volt normal range.				Switching to redundant power supply will extinguish status light.
	EPS status lights F/C-BUS DISCONNECT	Indicates a fuel cell has automatically disconnected from the d-c main buses.				Audio portion of master alarm circuit will not operate, as the 12-volt tone generator power will be interrupted by a power supply failure.
					SC2120X Fuel cell 1 bus A disconnect SC2121X Fuel cell 2 bus A disconnect SC2122X Fuel cell 3 bus A disconnect SC2125X Fuel cell 1 bus B disconnect SC2126X Fuel cell 2 bus B disconnect SC2127X Fuel cell 3 bus B disconnect	Yellow lamp illuminates when any fuel cell is disconnected from the S/M d-c bus A and/or B. The overload and reverse current units on each fuel cell automatically disconnect the fuel cell output from the bus when a reverse current >4 amps or a forward current >75 amps is sensed. The lamp will not illuminate when the affected fuel cell main bus switch is in the off position. Event indicators below the FUEL CELL-1, -2, and -3 MAIN BUS A and B switches indicate with a striped display which fuel cell is disconnected from which bus.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-11 (Cont)	F/C 1, F/C 2, and F/C 3	Indicates one of the following conditions exist in the respective fuel cell:  a. H <sub>2</sub> flow rate below 0.028 lb/hr or above 0.153 lb/hr          b. O <sub>2</sub> flow rate below 0.22 lb/hr or above 1.22 lb/hr          c. pH factor of 9 or over	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	a. SC2139R Flow rate H <sub>2</sub> F/C 1  SC2140R Flow rate H <sub>2</sub> F/C 2  SC2141R Flow rate H <sub>2</sub> F/C 3  b. SC2142R Flow rate O <sub>2</sub> F/C 1  SC2143R Flow rate O <sub>2</sub> F/C 2  SC2144R Flow rate O <sub>2</sub> F/C 3  c. SC2160X pH factor water condition F/C 1  SC2161X pH factor water condition F/C 2  SC2162X pH factor water condition F/C 3	Yellow lights illuminate when any of the sensed parameters are out of tolerance. Switching the FUEL CELL INDICATORS switch (MDC-18) to the position indicated by the illuminated status lights and observing the fuel cell displays, enables the crew to determine which parameter is out of tolerance. Alarm trigger values are presented in the Function column.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-11 (Cont)		d. F/C skin temperature below 360°F or above 500°F	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	d. SC2084T Temp F/C 1 skin  SC2085T Temp F/C 2 skin  SC2086T Temp F/C 3 skin	
		e. F/C condenser exhaust temperature below 155°F or above 175°F			e. SC2081T Temp F/C 1 cond exhaust  SC2082T Temp F/C 2 cond exhaust  SC2083T Temp F/C 3 cond exhaust	
		f. F/C outlet radiator temperature below -30°F			f. SC2087T Temp F/C 1 radiator outlet  SC2088T Temp F/C 2 radiator outlet  SC2089T Temp F/C 3 radiator outlet	

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-11 (Cont)		g. H <sub>2</sub> regulator pressure above 75 psia	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	g. SC2069P H <sub>2</sub> pres- sure F/C 1 regulated  SC2070P H <sub>2</sub> pres- sure F/C 2 regulated  SC2071P H <sub>2</sub> pres- sure F/C 3 regulated	
		h. O <sub>2</sub> regulator pressure above 75 psia			h. SC2066P O <sub>2</sub> pres- sure F/C 1 regulated  SC2067P O <sub>2</sub> pres- sure F/C 2 regulated  SC2068P O <sub>2</sub> pres- sure F/C 3 regulated	
		i. N <sub>2</sub> regulator pressure above 70 psia.			i. SC2060P N <sub>2</sub> pres- sure F/C 1 regulated  SC2061P N <sub>2</sub> pres- sure F/C 2 regulated	

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-11 (Cont)	INV 1 TEMP HI, INV 2 TEMP HI, and INV 3 TEMP HI	Indicates an overtemperature (241°F) exists in the respective inverter.	CAUT / WARN MN A MN B (MDC-25)	D-C main buses A and B	1. (Cont) SC2062P N2 pres- sure F/C 3 regulated	
					CC0175T (Temp static inverter 1) CC0176T (Temp static inverter 2) CC0177T (Temp static inverter 3)	The yellow inverter overtemperature lights illuminate at +241°F and above.
	MN BUS A UNDER- VOLT and MN BUS B UNDERVOLT	Indicates a d-c voltage drop below $26.25 \pm 0.1$ vdc on the respective d-c main bus.			None	The yellow main d-c bus undervoltage lights will not illuminate when the affected main bus reset switch is in the OFF position.
	AC BUS 1 FAIL and AC BUS 2 FAIL	Indicates the following conditions exist in any of the three phases of the respective a-c bus: a. Undervoltage ( $95 \pm 3$ vac) b. Overvoltage ( $130 \pm 2$ vac)				The yellow a-c bus fail lights will not illuminate when affected a-c bus reset switch is in the OFF position.  The inverters will not disconnect from the buses on an undervoltage condition, but will disconnect from bus on overload. Light must be reset.
	AC BUS 1 OVER- LOAD and AC BUS 2 OVERLOAD	Indicates an overload (3Ø, 9 amps/Ø for 15±5 seconds or 1Ø, 11 amps for 5±1 second) exists on the respective a-c bus.				The inverter supplying the bus will be automatically disconnected at the time either of these yellow lights illuminate. Time versus overload is 5±1 seconds for a short circuit of 300-percent-rated current per phase and 10(-0, +5) seconds for a short circuit of 250-percent-rated current. Lamps will not illuminate when affected a-c bus reset switch is in the OFF position.
	CAUT/WARN switches  POWER switch					The output of both power supplies is +12 and -12 vdc, which is used in the caution and warning system electronics.

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MDC-11 (Cont)	1	Applies d-c power to caution and warning system power supply No. 1.	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	None	Nominal switch position is 1.
	OFF	Removes d-c power from caution and warning system power supplies No. 1 and No. 2.				Power is still applied to the C&WS; however, the master alarm circuit and those status lights activated as the result of analog signals will be inoperative.
	2	Applies d-c power to caution and warning system power supply No. 2.				Power to C/M system status lights is not removed with switch in either position. Power is removed only by placing C/W switch (MDC-13) to ACK position.
	MODE switch					CSM mode is selected at all times prior to CSM separation. Power is applied to the following 15 S/M status lights: PITCH GMBL DR FAIL, YAW GMBL DR FAIL, SPS PU SNR FAIL, F/C BUS DISCONNECT, O <sub>2</sub> PRESS, H <sub>2</sub> PRESS, SPS PRESS, S/M RCS A, S/M RCS B, S/M RCS C, S/M RCS D, SPS WALL TEMP HI, F/C 1, F/C 2, and F/C 3.
	CSM	a. Applies d-c power to 15 S/M system status lights, permitting illumination of lights upon receipt of malfunction signals.				Power is applied to the following 4 S/M event channels: PITCH GMBL DR FAIL, YAW GMBL DR FAIL, SPS PU SNR FAIL, and F/C BUS DISCONNECT.
C/M		b. Applies d-c power to 4 S/M event channels, permitting circuitry to simulate lamp load when C/W switch is in ACK position.				
		c. Opens d-c ground return path, inhibiting C/M RCS A and C/M RCS B lamp circuits prior to CSM separation.				
		a. Removes d-c power to 15 S/M system status lights. b. Removes d-c power to 4 S/M event channels. c. Completes d-c ground return path, enabling C/M RCS A and C/M RCS B lamp circuits after CSM separation.				C/M mode is selected subsequent to CSM separation.

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MDC-11	DIGITAL EVENT TIMER window	The event timer provides the crew with a means of monitoring and timing events. Indications from 00 minutes and 00 seconds (00-00) to 59 minutes and 59 seconds (59-59) are obtainable in a countup or countdown mode. In a countup mode, when 59-59 is recorded, the counter will proceed to 00-00 and continue to count up. In a countdown mode, continuous counting is also available.	EVENT TIMER MN A MN B (MDC-25)	D-C main buses A and B	None	The event timer is a reference system only and is automatically reset to zero when an abort is automatically or manually initiated.  The event timer starts automatically when lift-off occurs.
	DIGITAL EVENT TIMER switches					
	RESET/UP/DOWN switch					
	RESET	Reset the event timer (MDC-5) to zero.				The event timer is automatically reset to zero and starts counting up when an abort is automatically or manually initiated. The switch is momentary on towards the RESET position and maintain on in the other two positions.
	UP	Completes circuitry for the event timer to time up.				
	DOWN	Completes circuitry for the event timer to time down.				
	START/STOP switch					The event timer starts automatically when lift-off occurs. The switch is momentary on towards the START position and maintain on in the other two positions.  The control switches provide a means of running the event timer to any desired setting and are spring-loaded to the center position. The indicating drums can be run up or down, depending on the position of the RESET/UP/DOWN switch.
	START	Starts the event timer.				
	Center	No function.				
	STOP	Stops the event timer.				
	MIN switch					
	TENS	Runs the MIN indicating drums in tens.				
	Center	No function.				
	UNITS	Runs the second MIN indicating drum in units.				
	SEC switch					
	TENS	Runs the SEC indicating drums of the event timer in tens.				
	Center	No function.				
	UNITS	Runs the second SEC indicating drum in units.				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-11 (Cont)	DIGITAL EVENT TIMER switches	The event timer provides the crew with a means of monitoring and timing events. Indications from 00 minutes and 00 seconds (00-00) to 59 minutes and 59 seconds (59-59) are obtainable in a countup or countdown mode. In a countup mode, when 59-59 is recorded, the counter will proceed to 00-00 and continue to count up. In a countdown mode, continuous counting is also available.	EVENT TIMER MN A MN B (MDC-25)	D-C main buses A and B	None	This event timer is for reference only.  The event timer starts automatically when lift-off occurs.
	RESET/UP/DOWN switch					
	RESET	Reset the event timer (MDC-11) to zero.				The switch is momentary on towards the RESET position and maintained on in the other two positions.
	UP	Completes circuitry for the event timer to time up.				
	DOWN	Completes circuitry for the event timer to time down.				
	START/STOP switch					The event timer starts automatically when lift-off occurs. The switch is momentary on towards the START position and maintained on in the other two positions.  The control switches provide a means of running the event timer to any desired setting and are spring-loaded to the center position. The indicating drums can be run up or down, depending on the position of the RESET/UP/DOWN switch.
	START	Starts the event timer.				
	Center	No function.				
	STOP	Stops the event timer.				
	MIN switch					
	TENS	Runs the MIN indicating drums in tens.				
	Center	No function.				
	UNITS	Runs the second MIN indicating drum in units.				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-12	S/M RCS indicators		INSTRUMENTS—ESS MN A MN B (MDC-22)	D-C main buses A and B	Package temp: A-SR5065T B-SR5066T C-SR5067T D-SR5068T	Four indicators are identical in operation. Each one consists of a dial and movable pointer. Pointer movement is vertical, as observed from crew couch. Each indicator is capable of accepting input signals from the C/M or S/M RCS. Displayed information is determined by the position of the RCS INDICATORS switch.
	TEMP	Indicates temperature of S/M RCS package A, B, C, or D, as selected by the RCS INDICATORS switch. (Meter range: 0° to 200°F.)				
	PKG					
	He	Indicates temperature of S/M RCS helium supply for A, B, C, or D, as selected by the RCS INDICATORS switch. (Meter range: 0 to 400 psia, must be transposed to degrees. Refer to Remarks.)				
	PRESS				He tank pressure: A-SR5001P B-SR5002P C-SR5003P D-SR5004P	The S/M RCS helium tank supply temperature is indicated as psia on this indicator. The range of the indicator is 0 to 400 psia, bottom to top scale. 0 psia is equivalent to 0°F and 400 psia is equivalent to 150°F. The indicated number (psia) on this indicator, plus the helium tank supply pressure readout (psia) would be utilized by the crew to determine on the nomogram the propellant quantity remaining in a given quad in percent.
	He	Indicates helium tank pressure of S/M RCS package A, B, C, or D, as selected by the RCS INDICATORS switch. (Meter range: 0 to 5000 psia.)				
	MANF	Indicates regulated helium pressure of S/M-RCS package A, B, C, or D, as selected by the RCS INDICATORS switch. (Meter range: 0 to 400 psia.)				
	C/M RCS indicators				Regulated He press: A-SR5729P B-SR5776P C-SR5817P D-SR5830P	
	TEMP	Indicates helium tank temperature of C/M RCS system A or B, as selected by the RCS INDICATORS switch. (Meter range: 0 to 200°F.)				
	He					
	PRESS				He tank temp: A-CR0003T B-CR0004T	
	He	Indicates helium tank pressure of C/M RCS system A or B, as selected by the RCS INDICATORS switch. (Meter range: 0 to 5000 psia.)				
	PRESS				He tank press: A-CR0001P B-CR0002P	
	He					

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-12 (Cont)	F	Indicates regulated helium pressure to the fuel tank of C/M RCS system A or B, as selected by the RCS INDICATORS switch. (Meter range: 0 to 400 psia.)	INSTRUMENTS— ESS MN A MN B (MDC-22)	D-C main buses A and B	Regulated He press (Fuel system) A-CR0005P B-CR0006P	
	OX	Indicates regulated helium pressure to the oxidizer tank of C/M RCS system A or B, as selected by the RCS INDICATORS switch. (Meter range: 0 to 400 psia.)			Regulated He press (OX system) A-CR0011P B-CR0012P	
	RCS INDICATORS switch	Selects inputs to the propellant temperature, and pressure indicating devices. C/M sections A and B functions are identical within their respective systems. S/M sections A, B, C, and D functions are identical within their respective systems.	N/A	N/A	None	Six-position rotary switch. C/M section of switch, positions A and B, permits monitoring command module propellant systems A and B. S/M section of switch, positions A, B, C, and D permits monitoring service module propellant systems of quads A, B, C, and D.
	C/M section A (B)  S/M section A (B, C, D)	Connects C/M RCS system A (B) signal outputs from temperature and pressure transducers to the appropriate indicating devices.  Connects S/M RCS quad A (B, C, and D) signal outputs from temperature and pressure transducers and the propellant quantity sensing computer to the appropriate indicating devices.				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-12 (Cont)	400-hour clock	Displays mission elapsed time in 10-hour increments up to 400 hours.	None	None	None	The indicator has two set-knobs. One starts, stops, and resets the clock; the other sets the hour and minute hands, and winds the clock.
MDC-13	C/W switch  NORMAL	Applies d-c power to the following:  a. Twenty-five C/M system status lights, permitting illumination of lights upon receipt of malfunction signals.  b. One pole of CAUT/WARN-MODE switch, which in turn may apply power to 15 S/M system status lights.  c. MASTER ALARM switch-light on MDC-3, permitting illumination of light upon receipt of malfunction signals.	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	None	Switch is set to NORMAL at all times other than during the ascent phase or when dark adaptation is required. With switch in this position and upon receipt of a malfunction signal, the appropriate system status light and the MASTER ALARM lights will illuminate, and an audio alarm tone is sent to each headset.  Power is applied to the following 25 C/M system status lights: CDU FAIL, G&N ACCEL FAIL, AGC PWR FAIL, IMU FAIL, G&N ERROR, IMU TEMP, GMBL LOCK, AGAP TEMP, SPS ROUGH ECO, H <sub>2</sub> O ACCUM FAIL, O <sub>2</sub> FLOW HI, AC BUS 1 FAIL, AC BUS 1 OVERLOAD, AC BUS 2 FAIL, AC BUS 2 OVERLOAD, MN BUS A UNDERVOLT, MN BUS B UNDERVOLT, INV 1 TEMP HI, INV 2 TEMP HI, INV 3 TEMP HI, C/M RCS A, C/M RCS B, GLYCOL TEMP LOW, CO <sub>2</sub> PP HI, and CAUT/WARN FAIL.  For a list of the 15 S/M system status lights, refer to Remarks column of CAUT/WARN-MODE switch (MDC-11), CSM position.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-13 (Cont)	BOOST	<p>a. Applies d-c power to 25 C/M system status lights, permitting illumination of lights upon receipt of malfunction signals.</p> <p>b. Applies d-c power to one pole of CAUT/WARN-MODE switch, which in turn may apply power to 15 S/M-systems status lights.</p> <p>c. Removes d-c power from MASTER ALARM switch-light on MDC-3, preventing illumination of light upon receipt of malfunction signals during the ascent phase.</p>	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	None	Switch set to BOOST at prelaunch to preclude the possibility of confusion on MDC-3 between the red MASTER ALARM light and the adjacent red ABORT light during the critical ascent phase.
	ACK	<p>a. Removes d-c power from 25 C/M system status lights, preventing illumination of lights upon receipt of malfunction signals.</p> <p>b. Removes d-c power from one pole of CAUT/WARN MODE switch, thereby removing power to 15 S/M system status lights.</p> <p>c. Places push-switch function of both MASTER ALARM switch-lights into the d-c circuit of the system status lights. This prevents illumination of the system status lights upon receipt of malfunction signals until either push-switch is pressed to complete the circuit.</p>				Switch is set to ACK to retain dark adaptation. With switch in this position and upon receipt of a malfunction signal, only the MASTER ALARM lights will illuminate and an alarm tone be sent to each headset. To determine the malfunction either MASTER ALARM switch-light may be pressed to illuminate the appropriate system status light. The light will remain illuminated only as long as the switch-light is pressed. Although upon release all system status lights are extinguished, they may be recalled as long as the malfunction exists by again pressing either switch-light.
	POWER switch	Controls power to senior pilots module in audio center equipment.	T/C GROUP 5 (MDC-22)	Flight and postlanding bus		The audio center will not be activated unless the POWER switch is in PTT or VOX position.
	PTT	Applies d-c power to audio and control circuits.				Intercom capability when cobra cable PTT/CW switch is in CW and transmit capability with PTT/CW switch in PTT.
	OFF	Removes power from senior pilots audio center equipment module and controls.				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-13 (Cont)	VOX	a. Applies d-c power to audio and control circuits. b. Enables VOX control of mike amplifier by supplying ground to VOX circuitry.	T/C GROUP 5 (MDC-22)	Flight and postlanding bus	None	VOX operation permits voice transmission and transmitter keying of intercom, HF Recovery transceiver and voice recorder when cobra cable PTT/CW switch is at PTT.
	S-BAND switch					
	T/R	No effect. S-Band T/R function supplied by cobra cable PTT key.				The S-BAND, HF, VHF-AM, and INTERCOM switches all control ground return paths for appropriate diode switching and isolation circuitry in the senior pilots module of the audio center equipment to allow transmission and reception, or reception alone, of voice signals over selected equipment. The HF and VHF-AM switches also provide ground return paths for the HF and VHF-AM transmitter keying circuits when in the T/R position.
	OFF	Prevents senior pilot from transmitting or receiving voice over USBE.				
	REC	Enables senior pilot to receive voice from USBE.		Audio center equipment		
	RCDR/HF switch		N/A			
	T/R	a. Enables senior pilot to transmit and receive voice over HF transceiver when operating in AM or SSB mode. b. Enables voice recorder through VOX circuit.				Provides power ground through audio center VOX circuit for HF transmitter transmit-receive relay and voice recorder power relay.
	OFF	Prevents senior pilot from transmitting or receiving voice over HF transceiver.				
	REC	Enables senior pilot to receive voice from HF transceiver when operating in AM or SSB mode.				
	VHF-AM switch					VHF-AM transmits, in addition to S-Band voice, when cobra cable PTT key is closed. Cobra cable PTT/CW switch must be at PTT, and audio center POWER switch must be at PTT.
	T/R	Enables senior pilot to transmit and receive voice over VHF-AM transmitter-receiver when operating in T/R mode.				
	OFF	Prevents senior pilot from transmitting or receiving voice over VHF-AM transmitter-receiver.				

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MDC-13 (Cont)	REC	Enables senior pilot to receive voice from VHF-AM transmitter-receiver.	N/A	Audio center equipment	None	
	INTERCOM switch					
	T/R	Enables senior pilot to transmit and receive voice over the intercom system.				Audio center POWER switch must be at VOX to enable mike amplifier when cobra cable PTT/CW switch is at PTT.
	OFF	Prevents senior pilot from transmitting or receiving voice over intercom system.				
	REC	Enables senior pilot to receive voice from intercom system.				
	VOX SENS control	Increases or decreases sensitivity of voice-operated relay circuitry in senior pilots audio center module.				These three controls are thumbwheel-type potentiometers which may be rotated upward or downward, as required.
	INTERCOM BALANCE control	Increases or decreases level of audio signal received by senior pilot from RF equipment relative to that received from intercom bus.				Position 9 most sensitive.
	VOLUME control	Increases or decreases level of audio signal from senior pilots earphone amplifier to earphone.				
	TANK PRESSURE indicators H <sub>2</sub> group	Displays H <sub>2</sub> tank No. 1 and No. 2 pressure and is used as follows: a. Determine tank heater performance. b. Detect leaks.				Displays for H <sub>2</sub> and O <sub>2</sub> tanks No. 1 and 2 operate prior to CSM separation only.
	Indicators 1 and 2		ESSEN-TIAL-3 (RHEB 204) S/M	S/M INST PWR DIST	SF0039P (Press H <sub>2</sub> tank No. 1) SF0040P (Press H <sub>2</sub> tank No. 2)	The indicator function is controlled by pressure transducers located in H <sub>2</sub> tank No. 1 and No. 2 outlet lines. These transducers are also connected to C&WS, operating the H <sub>2</sub> PRESS light on MDC-10. H <sub>2</sub> operating range is 230 to 260 psia. Alarm trigger values are 220 psia low, and 270 psia high.

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MDC-13 (Cont)	O <sub>2</sub> group Indicator 1	Displays pressure of O <sub>2</sub> tank No. 1 or ECS surge tank as selected by O <sub>2</sub> PRESS IND switch (MDC-13) and is used as follows: a. Determine tank heater performance. b. Detect leaks. c. Verify surge tank pressure.	ESSENTIAL-3 (RHEB 204) and fuse in S/M	S/M INST PWR DIST	SF0037P (Press O <sub>2</sub> tank No. 1)  CF0006P (Press surge tank)	With O <sub>2</sub> PRESS IND switch at TANK 1, the indicator function is controlled by a pressure transducer located in O <sub>2</sub> tank No. 1 outlet line. Transducer also connected to C&WS, operating O <sub>2</sub> PRESS light on MDC-10. O <sub>2</sub> operating range is 865 to 935 psia. Alarm trigger values are 800 psia low and 950 psia high. With O <sub>2</sub> PRESS IND switch at SURGE TANK position, indicator displays signal from ECS surge tank pressure transducer.
	Indicator 2	Displays O <sub>2</sub> tank No. 2 pressure and is used as follows: a. Determine tank heater performance. b. Detect leaks.			SF0038P (Press O <sub>2</sub> tank No. 2)	The indicator function is controlled by a pressure transducer located in O <sub>2</sub> tank No. 2 outlet line. Transducer also connected to C&WS, operating O <sub>2</sub> PRESS light on MDC-10. O <sub>2</sub> operating range is 865 to 935 psia. Alarm trigger values are 800 psia low, and 950 psia high.
	TANK QUANTITY indicator H <sub>2</sub> group Indicator 1	Displays quantity of H <sub>2</sub> remaining in tank No. 1.	CRYO-GENIC SYSTEM-QTY AMPL 1 AC 1 - ØC (MDC-22)	A-C bus No. 1 ØC	SF0030Q (Quantity H <sub>2</sub> tank No. 1)	H <sub>2</sub> quantity display range is 0 to 28 lb.
	Indicator 2	Displays quantity of H <sub>2</sub> remaining in tank No. 2.	CRYO-GENIC SYSTEM-QTY AMPL 2 AC 2 - ØC (MDC-22)	A-C bus No. 2 ØC	SF0031Q (Quantity H <sub>2</sub> tank No. 2)	

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MDC-13 (Cont)	O <sub>2</sub> group					
	Indicator 1	Displays quantity of O <sub>2</sub> remaining in tank No. 1.	CRYO-GENIC SYSTEM - QTY AMPL 1 AC 1 - ØC (MDC-22)	A-C bus No. 1 ØC	SF0032Q (Quantity O <sub>2</sub> tank No. 1)	O <sub>2</sub> quantity display range is 0 to 320 lb.
	Indicator 2	Displays quantity of O <sub>2</sub> remaining in tank No. 2.	CRYO-GENIC SYSTEM - QTY AMPL 2 AC 2 - ØC (MDC-22)	A-C bus No. 2 ØC	SF0033Q (Quantity O <sub>2</sub> tank No. 2)	
	H <sub>2</sub> HEATERS switches					
	Switches 1 and 2	Controls d-c power to H <sub>2</sub> tanks No. 1 and 2 heater elements, respectively.	CRYO-GENIC SYSTEM - TANK	D-C main bus A	None	Redundant heater elements in each H <sub>2</sub> tank requires 10 watts of power for each element.
	AUTO	Enables automatic pressure switches to control d-c power to H <sub>2</sub> tanks No. 1 and 2 heater elements.	HEATERS - H <sub>2</sub> - 1 MN A (MDC-22)			Switch at AUTO position will apply d-c voltage to H <sub>2</sub> tanks No. 1 and 2 redundant heater elements when pressure switches in both tanks are in a low-pressure position at 230 psia or lower, and remove d-c voltage when either pressure switch is in a high-pressure position at 260 psia or higher.
	OFF	Disconnects d-c power from H <sub>2</sub> tanks No. 1 and 2 heater elements.	CRYO-GENIC SYSTEM - TANK HEATERS - H <sub>2</sub> - 2 MN B (MDC-22)	D-C main bus B		
	ON	Controls d-c power directly to H <sub>2</sub> tanks No. 1 and 2 heater elements.				Switch at ON (manual) position bypasses the pressure switches applying d-c voltage directly to the same redundant heater elements employed for automatic operation.

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MDC-13 (Cont)	O <sub>2</sub> HEATERS switches Switches 1 and 2	Controls d-c power to O <sub>2</sub> tanks No. 1 and 2 heater elements, respectively.	CRYOGENIC SYSTEM - TANK HEATERS - O <sub>2</sub> - 1 MN A (MDC-22)	D-C main bus A	None	Redundant heater elements in each O <sub>2</sub> tank requires 77.5 watts of power for each element.
	AUTO	Enables automatic pressure switches to control d-c power to O <sub>2</sub> tanks No. 1 and 2 heater elements.	CRYOGENIC SYSTEM - TANK HEATERS - O <sub>2</sub> - 2 MN B (MDC-22)	D-C main bus B		Switch at AUTO position will apply d-c voltage to O <sub>2</sub> tanks No. 1 and 2 redundant heater elements when pressure switches in both tanks are in a low-pressure position at 865 psia or lower and will remove d-c voltage when either pressure switch is in a high-pressure position at 935 psia or higher.
	OFF	Disconnects d-c power from O <sub>2</sub> tanks No. 1 and 2 heater elements.				
	ON	Controls d-c power directly to O <sub>2</sub> tanks No. 1 and 2 heater elements.				Switch at ON (manual) position bypasses the pressure switches, applying d-c voltage directly to the same redundant heater elements employed for automatic operation.
O <sub>2</sub> PRESS IND switch	TANK 1	Connects output of O <sub>2</sub> tank No. 1 pressure transducer to O <sub>2</sub> tank No. 1 TANK PRESSURE indicator (MDC-13).	ESSENTIAL - 3 (RHEB 204) and fuse in S/M	S/M INSTR PWR DIST	SF0037P (Press O <sub>2</sub> tank 1)	TANK PRESSURE - 1 - O <sub>2</sub> indicator is shared by two pressure signals. Normal position of switch prior to CSM separation except for periodic surge tank readouts.
	SURGE TANK	Connects output of ECS SURGE TANK pressure transducer to O <sub>2</sub> tank No. 1 TANK PRESSURE indicator.	INSTRUMENTS - ESS - MN A and MN B (MDC-22), also ESSENTIAL - 2 (RHEB 204)	D-C main buses A and B	CF0006P (Press surge tank)	Normal position of switch following CSM separation.

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MDC-13 (Cont)	H <sub>2</sub> FANS switches Switches 1 and 2	Controls a-c power to H <sub>2</sub> tanks No. 1 and 2 fan motors, respectively.	CRYOGENIC TANK FAN MOTORS -1- AC 1	A-C bus No. 1	None	Redundant fan motors in each H <sub>2</sub> tank requires 63VA total.
	AUTO	Applies a-c power to contacts on motor switch which controls 3Ø a-c power to circulating fan motors in H <sub>2</sub> tanks No. 1 and 2.	ØA ØB ØC (MDC-22)			Switch at AUTO position will apply a-c voltage to H <sub>2</sub> tanks No. 1 and 2 redundant fan motors when pressure switches in both tanks are in a low-pressure position at 230 psia or lower and will remove a-c voltage when either pressure switch is in a high-pressure position at 260 psia or higher.
	OFF	Disconnects 3Ø a-c power from H <sub>2</sub> tanks No. 1 and 2 circulating fan motors.	CRYOGENIC TANK FAN MOTORS -2- AC 2	A-C bus No. 2		Switch at ON (manual) position bypasses the pressure switches, applying a-c power directly to the same redundant H <sub>2</sub> tank fan motors employed for automatic operation.
	ON	Controls 3Ø a-c power directly to circulating fan motors in H <sub>2</sub> tanks No. 1 and 2	ØA ØB ØC (MDC-22)			Redundant fan motors in each O <sub>2</sub> tank requires 148VA total.
O <sub>2</sub> FANS switches Switches 1 and 2	AUTO	Applies a-c power to contacts on motor switch which controls 3Ø a-c power to circulating fan motors in O <sub>2</sub> tanks No. 1 and 2.	CRYOGENIC TANK FAN MOTORS -1- AC 1	A-C bus No. 1		Switch at AUTO position will apply a-c power to O <sub>2</sub> tank No. 1 and 2 redundant fan motors when pressure switches in both tanks are in a low-pressure position at 865 psia or lower and will remove a-c voltage when either pressure switch is in a high-pressure position at 935 psia or higher.
	OFF	Disconnects 3Ø a-c power from O <sub>2</sub> tanks No. 1 and 2 circulation fan motors.	ØA ØB ØC (MDC-22)			Switch at ON (manual) position bypasses the pressure switches, applying a-c power directly to the same redundant O <sub>2</sub> tank fan motors employed for automatic operation.
	ON	Controls 3Ø a-c power directly to circulating fan motors in O <sub>2</sub> tanks No. 1 and 2.	CRYOGENIC TANK FAN MOTORS -2- AC 2	A-C bus No. 2		
			ØA ØB ØC (MDC-22)			
GLY EVAP STEAM PRESS indicator		Provides pressure indication of steam discharged from water-glycol evaporator.	ECS - TRANS-DUCER PRESS GROUPS 2 MN A MN B (MDC-22)	D-C main buses A and B	CF0034P (Press glycol evap out steam)	Normal steam duct pressure operating range is 0.97 to 0.145 psia.

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MDC-13 (Cont)	PRESS GLY DISCH indicator	Provides static pressure indication of water-glycol pump discharge.	ECS-TRANS-DUCER-PRESS GROUPS 1 MN A MN B (MDC-22)	D-C main buses A and B	CF0016P (Press glycol pump outlet)	Normal water-glycol pump operating range indications are as follows: Prelaunch (GSE and onboard pumps): 14 to 18 psia Prelaunch (onboard pumps): 45 to 55 psia Normal flight: 37 to 45 psia Emergency flight: 37 to 45 psia
	FLOW O <sub>2</sub> indicator	Provides total rate-of-flow indication of oxygen supplied to the ECS downstream of the flow transducer.	ECS-TRANS-DUCER-PRESS GROUPS 2 MN A MN B (MDC-22)		CF0035R (Flow rate ECS O <sub>2</sub> )	Indicator will not show O <sub>2</sub> flow upstream of transducer, such as through PLSS FILL valve (LHEB-314) main regulator or surge tank relief valve action, or line leakage. O <sub>2</sub> FLOW HI system status light (red) is located on MDC-11 and illuminates at a flow rate of 1.0 lb/hr. Normal O <sub>2</sub> flow operating range indications are from 0.20 to 0.45 lb/hr during prelaunch and in flight.
	ΔP SUIT COMPR indicator	Provides pressure differential indication between suit compressor inlet and outlet manifolds to determine degree of compressor efficiency.	ECS-TRANS-DUCER-PRESS GROUPS 1 MN A MN B (MDC-22)		CF0015P (Press suit compressor diff)	Suit compressor ΔP operating range indications are as follows: 0.7 to 0.9 psi during prelaunch 0.3 to 0.4 psi during normal space flight 0.2 to 0.3 psi during emergency space flight.
	GLY ACCUM-QUANTITY indicator	Provides quantity indication of water-glycol in accumulator.			CF0019Q (Quantity glycol accum)	Capacity of accumulator is 1.36 lb. Normal accumulator operating range indications are as follows: Prelaunch (GSE) and onboard pump): 0% Normal flight: 40 to 60% Emergency flight: 40 to 60%
	WATER-QUANTITY indicator	Provides quantity indication of waste water tank or potable water tank as selected by H <sub>2</sub> O IND switch (MDC-13).	ECS-TRANS-DUCER-WASTE & POT H <sub>2</sub> O MN A MN B (MDC-22)		CF0009Q (Quantity waste water tank) CF0010Q (Quantity potable H <sub>2</sub> O tank)	Capacities of the water tanks are 36 lb of potable water and 56 lb of waste water. Water quantity indications are dependent upon a selected mission profile and specific times during the mission.

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MDC-13 (Cont)	ECS RAD-OUTLET TEMP indicator	Provides temperature indication of water-glycol returned to C/M from S/M space radiators (or from GSE during prelaunch).	ECS TRANS-DUCER TEMP MN A MN B (MDC-22)	D-C main buses A and B	CF0020T (Temp space radiator outlet)	GLYCOL TEMP LOW system status light (yellow) is located on MDC-11, and illuminates at -30°F.  Normal ECS radiator outlet temperature operating range is 30° to 102°F.
	GLY EVAP-OUTLET TEMP indicator	Provides temperature indication of water-glycol at outlet of water-glycol evaporator.				
	TEMP indicators					
	SUIT	Provides temperature indication of suit circuit atmosphere.			CF0008T (Temp suit supply main)	Temperature sensor located in suit heat exchanger outlet duct.  Normal suit circuit operating range indications are 45° to 55°F during prelaunch and in flight.
	CABIN	Provides average temperature indication of cabin atmosphere.			CF0002T (Temp cabin)	Sensor located near inlet to cabin air fans.  Normal cabin operating range indications are 50° to 70°F during prelaunch and 70° to 80°F in flight.
	PRESS indicators	Provides pressure indication of suit circuit atmosphere.	ECS-TRANS-DUCER PRESS GROUPS 1 MN A MN B (MDC-22)		CF00012P (Press suit demand reg sense)	Pressure transducer located at demand regulator sensing port.  Normal suit circuit operating range indications are as follows: 14.7 psia during prelaunch, 4.7 to 5.3 psia during normal flight mode, and 3.75±0.25 psia during emergency flight mode.

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MDC-13 (Cont)	CABIN	Provides pressure indication of cabin atmosphere.	ECS - TRANS-DUCER - PRESS GROUPS 2 MN A MN B (MDC-22)	D-C main buses A and B	CF0001P (Pressure cabin)	Pressure transducer located inside LHFEB.  Normal cabin operating range indications are as follows: 14.7 psia during prelaunch, 4.8 to 5.2 psia during normal space flight, and 0.0 psia during emergency space flight.
	PART PRESS CO <sub>2</sub> indicator	Provides partial pressure indication of CO <sub>2</sub> in suit circuit atmosphere.	ECS - TRANS-DUCER - PRESS GROUPS 2 MN A (MDC-22)	D-C main bus A	CF0005P (Press CO <sub>2</sub> partial)	CO <sub>2</sub> sensor is located between inlet and outlet manifolds of suit circuit in LHEB.  The CO <sub>2</sub> partial pressure normal metabolic operating range is 0.0 to 7.6 mm Hg, and the emergency metabolic operating range is 7.6 to 15.0 mm Hg. Both ranges are for an unlimited length of time.  CO <sub>2</sub> PP HI system status light (MDC-11) illuminates at 7.6 mm Hg. This indicates CO <sub>2</sub> level has risen to the upper end of the normal operating range.
	H <sub>2</sub> O ACCUM switches AUTO 1/MAN/ AUTO 2 switch	a. Removes d-c power from H <sub>2</sub> O ACCUM-ON 1/ON 2 switch (MDC-13). b. Applies d-c power to No. 1 cyclic accumulator control unit to automatically time and actuate No. 1 cyclic accumulator valve for 10 seconds every 10 minutes.	ECS-H <sub>2</sub> O ACCUM-MN A (MDC-22)	D-C main bus A	None	In automatic mode, 10-second pulse signal for accumulator operation is received from GTE.
	MAN	a. Removes d-c power from No. 1 and No. 2 cyclic accumulator control units. b. Applies d-c power to H <sub>2</sub> O ACCUM-ON 1/ON 2 switch, permitting manual control of No. 1 or No. 2 cyclic accumulator valves.	ECS-H <sub>2</sub> O ACCUM-MN A MN B (MDC-22)	D-C main buses A and B		Switch position selects manual backup mode, permitting manual cyclic accumulator valve actuation in event both cyclic accumulator automatic control units should fail.

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MDC-13 (Cont)	AUTO 2	a. Removes d-c power from H <sub>2</sub> O ACCUM-ON 1/ON 2 switch. b. Applies d-c power to No. 2 cyclic accumulator control unit to automatically time and actuate No. 2 cyclic accumulator valve for 10 seconds every 10 minutes.	ECS - H <sub>2</sub> O ACCUM-MN B (MDC-22)	D-C main bus B	None	
	ON 1/ON 2 switch					
	ON 1	Back up switch position to apply d-c power to solenoid valve of No. 1 cyclic accumulator, manually controlling oxygen flow to accumulator.  Removes power from both solenoid valves, shutting off oxygen flow to either accumulator.	ECS - H <sub>2</sub> O ACCUM-MN A (MDC-22)	D-C main bus A		Switch position is momentary to preclude possibility of expending oxygen needlessly. Switch may be operated when convenient or when suit circuit humidity level becomes uncomfortable.
	Off (center)					
	ON 2	Back up switch position to apply d-c power to solenoid valve of No. 2 cyclic accumulator, manually controlling oxygen flow to accumulator.	ECS - H <sub>2</sub> O ACCUM-MN B (MDC-22)	D-C main bus B		This switch position is momentary to preclude possibility of expending oxygen needlessly. Switch may be operated when convenient or when suit circuit humidity level becomes uncomfortable.
	WASTE H <sub>2</sub> O TK REFILL switch		POT H <sub>2</sub> O HTR MN B (MDC-22)			Switch positions are not momentary; therefore, water quantity indicators must be monitored to prevent overfilling.  Potable tank will fill first, unless POTABLE TANK INLET valve is closed. Flow is at the rate of 2.92 lb per minute.
	1	Applies d-c power to solenoid valve of S/M water tank No. 1, permitting water flow to refill C/M water tanks.				
	OFF	Removes power from both solenoid valves.				
	2	Applies d-c power to solenoid valve of S/M water tank No. 2, permitting water flow to refill C/M water tanks.				

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MDC-13 (Cont)	SUIT EVAP switch  AUTO	Applies a-c power to the following to automatically regulate suit circuit temperature by the water-glycol or water evaporation cooling modes: a. Suit evaporator wetness control unit b. Steam pressure control unit c. Diverter valve control unit.	ECS - GLYCOL PUMPS - AC 1 ØB (MDC-22)	A-C bus No. 1	None	The AUTO position must be selected in conjunction with the use of the SUIT HT EXCH switch (LHEB-310).  The control unit temperature sensor is located in the suit evaporator outlet. The suit temperature indicator sensor, however, is located at the suit heat exchanger outlet duct.  The MAN position is selected in event of failure of any automatic control unit.
	MAN	Removes a-c power from the following to permit manual override operation of SUIT EVAP GLYCOL valve (LHEB-314): a. Suit evaporator wetness control unit b. Steam pressure control unit c. Diverter valve control unit.				
	H <sub>2</sub> O IND switch  POT  WASTE	Selects potable water tank quantity signal for display on WATER-QUANTITY indicator (MDC-13).  Selects waste water tank quantity signal for display on WATER-QUANTITY indicator.	ECS - TRANS- DUCER - WASTE & POT H <sub>2</sub> O - MNA MJB (MDC-22)	D-C main buses A and B		WATER-QUANTITY indicator is shared by two quantity signals.
	GLYCOL EVAP switches  H <sub>2</sub> O FLOW switch  AUTO	a. Applies a-c power to water control section. b. Closes circuit from control section to water control valve for automatically regulating water inflow to water-glycol evaporator.	ECS - GLYCOL PUMPS - AC 1 ØC (MDC-22)	A-C bus No. 1		
	Off (center)	Removes a-c power from water control section and d-c power from water control valve.				Water control valve is solenoid-operated.

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MDC-13 (Cont)	ON	Manual backup mode to apply d-c power to solenoid-operated water control valve, which opens valve and permits water to enter water-glycol evaporator.	ECS - POT H <sub>2</sub> O HTR MN A MN B (MDC-22)	D-C main buses A and B	None	This switch position is not momentary. Close coordination between switch actuation and the GLY EVAP-OUTLET TEMP indicator (MDC-13) is necessary to obtain correct water-glycol temperature and/or to prevent flooding the evaporator.
	STEAM PRESS group AUTO/MAN switch AUTO	a. Removes a-c power from GLYCOL EVAP - STEAM PRESS - INCR/DECR switch (MDC-13). b. Applies a-c power to steam pressure control section. c. Closes circuit from control section to steam pressure control valve to automatically regulate pressure in steam duct.	ECS- GLYCOL PUMPS- AC 1 ØC (MDC-22)	A-C bus No. 1		Steam pressure control valve full-travel requires 58 seconds (max).
	MAN	a. Removes a-c power from steam pressure control section. b. Opens circuit from control section to steam pressure control valve. c. Applies a-c power to GLYCOL EVAP-STEAM PRESS-INCR/DECR switch.				This switch position selects manual backup mode, permitting manual operation of steam pressure control valve actuator in event of steam pressure control section malfunction.
	INCR/DECR switch INCR	Applies a-c power to actuator of steam-pressure control valve, which moves valve in the closed direction and increases the steam duct pressure.				This switch position is momentary. Until motor-driven steam pressure control valve reaches its maximum limit, short periods of switch activation result in proportional increases in steam duct pressure. Valve full-travel requires 58 seconds (max).
	Off (center)	Removes a-c power from valve actuator.				

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MDC-13 (Cont)	DECR	Applies a-c power to actuator of steam pressure control valve, which moves valve in the open direction and decreases the steam duct pressure.	ECS-GLYCOL PUMPS-AC 1 ØC (MDC-22)	A-C bus No. 1	None	This switch position is momentary. Until motor-driven steam pressure control valve reaches its maximum limit, short periods of switch activation result in proportional decreases in steam duct pressure. Valve full-travel requires 58 seconds (max).
	TEMP IN switch					
	AUTO	Applies a-c power to water-glycol temperature control unit, which automatically regulates temperature of coolant entering evaporator by mixing hot and cold water-glycol.	ECS-GLYCOL PUMPS-AC 1 ØA (MDC-22)			Temperature control unit sensor is located at inlet to water-glycol evaporator.
	MAN	Removes a-c power from water-glycol temperature control unit, permitting manual override operation of GLYCOL EVAP TEMP IN valve (LHEB-311) by T-handle tool.				Water-glycol evaporator temperature control valve full travel requires 37.5 seconds (max).
						Manual control of water-glycol evaporator temperature control valve is required in event of failure of automatic control unit. Close coordination between valve adjustments and GLY EVAP-OUTLET TEMP and ECS RAD-OUTLET TEMP indicators (MDC-13) is necessary to obtain correct water-glycol temperature.
	CABIN TEMP controls					
	AUTO/MAN switch					
	AUTO	Applies a-c power to cabin temperature control unit to automatically regulate temperature of water-glycol flow through cabin heat exchanger.	ECS-CABIN AIR FAN 2 ØC (MDC-22)	A-C bus No. 2		Temperature control unit sensor is located at inlet to cabin air fans; also, an anticipator (sensor) is located at outlet of cabin air fans.
	MAN	Removes a-c power from cabin temperature control unit, permitting manual override operation of the CABIN TEMP control valve (LHFEB-303) by properly positioning control knob.				Cabin temperature control valve full travel requires 25 seconds (max).
						Manual control of cabin temperature control valve is required in event of failure of automatic control unit. There is a definite time lag in cabin temperature response following a manual adjustment; therefore, close coordination between manual adjustments and the TEMP-CABIN indicator (MDC-13) is not necessary.

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MDC-13 (Cont)	AUTO control INCR (upward)	Thumbwheel permits manual adjustment of cabin temperature automatic control unit. The higher the number selected, the greater proportional increase in cabin temperature.	None	None	None	Cabin temperature can be selected between 70° and 80°F. Numbers on thumbwheel do not correspond to any temperature.
	COMP FAIL light	Indicates AGC malfunction.	G&N - COMPUTER MN A MN B (MDC-22)	D-C main buses A and B	None	Request for operator to press KEY RLSE pushbutton.
MDC-14 AGC DSKY panel	KEY RLSE light	Internal AGC program needs DSKY circuits to continue program.				
	UPTL switch	Controls acceptance of telemetered data from MSFN.	GG5021X (AGC alarm 2)		None	
	ACCEPT BLOCK	Allows AGC to accept data from MSFN. Inhibits AGC reception of MSFN data.				
	ACTIVITY lights	Indicates activity the computer is presently engaged in.				
	UPTL COMP	AGC is receiving data link information by telemetry. AGC is engaged in computation.				
	PROGRAM indicator	A two-digit display indicating the number of the program (major mode) presently in progress.				On-board data provides definition of PROGRAM, NOUN, and VERB digits.
	VERB indicator	A two-digit display indicating verb code selected.				
	NOUN indicator	A two-digit display indicating noun code selected.				
	REGISTER 1 indicator	Displays contents of selected register or memory location. First component of extended-length data word, if applicable.				Displays may be selected manually or by AGC program.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-14 (Cont)	REGISTER 2 indicator	Displays contents of selected register or memory location. Second component of extended-length data word, if applicable.	G&N COMPUTER MN A MN B (MDC-22)	D-C main buses A and B	None	Displays may be selected manually or by AGC program.
	REGISTER 3 indicator	Displays contents of selected register or memory location. Third component of extended-length data word, if applicable.				
	BRIGHTNESS control	Varies brightness of electro-luminescent data displays: REGISTER 1, REGISTER-2, and REGISTER 3.				
	KEY RLSE pushbutton	Enables program control of DSKYs. Releases operator control of DSKY circuits.				Verifies alarms. Alarms triggered by transients should not repeat.
	ERROR RESET pushbutton	Resets alarm light relays. AGC recycles to start of current operation.				
	Keyboard switches	Provide for entering data into or commanding operation of the AGC.				Pushbutton-type switches (selectors). Each key generates a specific 5-bit key code denoting the instruction or number being selected.
	CLEAR	Place all zeros (logic 0s) in register being loaded.				
	VERB	Sets computer to accept next two digits as verb code.				
	NOUN	Sets computer to accept next two digits as noun code.				
	ENTER	Transfers contents of input register to central processor and initiates execution of instructions.				
	+	Denotes data to follow has positive decimal value.				
	-	Denotes data to follow has negative decimal value.				
	0 to 9	Enters the binary equivalent of the key pressed.				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-15	H <sub>2</sub> PURGE LINE HTR switch					
	ON	Applies +28 vdc power to two 2-watt heaters in fuel cell H <sub>2</sub> vent line.	FUEL CELL 1 - PURGE and FUEL CELL 2 - PURGE (MDC-22)	D-C main buses A and B	None	Two-position double-pole toggle switch provides heater power during H <sub>2</sub> purge of fuel cells. Positioned to ON 30 min before H <sub>2</sub> purge.
	OFF	Remove +28 vdc power from heaters.				Positioned to OFF after completing H <sub>2</sub> purge.
	HELIUM 1 switches	Four functionally identical switches. Each switch controls one helium isolation valve in the HELIUM 1 half of a parallel helium pressurization system. Each of the four RCS packages contains identical systems.	RCS-PROP ISOL MN A MN B (MDC-25)			Each switch is a three-position toggle switch, spring-loaded, causing it to return to the center position after setting it to the ON or OFF position. Each valve contains a position micro-switch which completes the circuit for operating the valve position event indicator mechanism. Each valve also contains an open and close mechanical latching feature.
	A (B, C, D)					
	ON	Energizes helium isolation valve solenoid that drives the valve to the open position.				
	Center	Removes solenoid excitation; valve remains in last commanded position.				
	OFF	Energizes helium isolation valve solenoid that drives the valve to the closed position.				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-15 (Cont)	HELIUM 1 event indicators A (B, C, D)	Striped-line display indicates closed condition of valve controlled by switch located directly above event indicator. Gray display indicates open condition.	RCS-PROP ISOL MN A MN B (MDC-25)	D-C main buses A and B	None	Each indicator is a two-position device with striped-line display controlled by solenoid action and gray display by permanent magnet action.
	HELIUM 2 switches  A (B, C, D)	Four functionally identical switches. Each switch controls one helium isolation valve in the HELIUM 2 half of a parallel helium pressurization system. Each of the four RCS packages contain identical systems.				Each switch is a three-position toggle switch, spring loaded, causing it to return to the center position after placing it to the ON or OFF positions. Each valve contains a position microswitch which completes the circuit for operating the valve position event indicator.
	ON	Energizes helium isolation valve solenoid that drives the valve to the open position.				Each indicator is a two-position device with striped-line display controlled by solenoid action and gray display by permanent magnet action.
	Center	Removes solenoid excitation; valve remains in last commanded position.				
	OFF	Energizes helium isolation valve solenoid that drives the valve to the closed position.				Each switch is a three-position toggle switch, spring-loaded, causing it to return to the center position after placing it to the ON or OFF positions. Each valve contains a position microswitch which completes the circuit for operating the valve position event indicator. Each valve is magnetically latched open and spring-loaded closed.
	HELIUM 2 event indicators A (B, C, D)	Striped-line display indicates closed condition of valve controlled by switch located directly above event indicator. Gray display indicates open condition.				
	PROPELLANT switches	Four functionally identical switches. Each switch controls two isolation valves (one fuel, one oxidizer) within each of the four S/M RCS packages.				

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MDC-15 (Cont)	A (B, C, D)  ON	Energizes propellant isolation valve solenoids that drive two valves to the open position.	RCS-PROP ISOL MN A MN B (MDC-25)	D-C main buses A and B	None	
	Center	Removes solenoid excitation; valves remain in last commanded position.				
	OFF	Energizes propellant isolation valve solenoids that drive two valves to the closed position.				
	PROPELLANT event indicators  A (B, C, D)	Striped-line display indicates closed condition of valves controlled by switch located directly above event indicator. Gray display indicates open condition.				
	C/M-S/M SEP switches  Switch 1 and 2  Up	Activates systems A and B to perform the following functions: a. C/M-S/M deadface b. C/M-RCS pressurize c. C/M-S/M separation d. Transfer entry batteries to d-c main buses A and B e. C/M-S/M separation pyro control shut-off f. RCS control transfer g. C/M-S/M separation signal to SMJC.  Off position.	MASTER EVENT SEQ CONT A ARM B BAT A and BAT B (MDC-22)	Battery buses A and B	CD0023X CM-SM separate relay close A CD0024X CM-SM separate relay close B	The switches are spring-loaded to the down position.  The two switches are guarded redundant switches.
	Down  C/M RCS PRPLNT group	Two functionally identical switches. Each switch controls two isolation valves (one fuel, one oxidizer) within its respective propellant system.	RCS-PROP ISOL MN A MN B (MDC-25)	D-C main buses A and B		Each switch is a three-position switch. Switch is spring-loaded from the OFF position to center position only. Each valve contains a position microswitch which completes the circuit for operating the valve position event indicator mechanism. Each valve also contains an open and close latching feature.

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MDC-15 (Cont)	A (B) switch	Energizes propellant isolation valve solenoids that drive two valves to the open position.	RCS-PROP ISOL MN A MN B (MDC-25)	D-C main buses A and B	None	Each indicator is a two-position device with striped-line display controlled by solenoid action and gray display by permanent magnet action. Indicator will function (striped-line display) if either valve is in a closed position.
	ON	Removes solenoid excitation; valves remain in last commanded position.				
	Center	Energizes propellant isolation valve solenoids that drive two valves to the closed position.				
	OFF	Striped-line display indicates closed condition of valves controlled by switch located directly above event indicator. Gray display indicates open condition.				
	A (B) event indicators					
MDC-16	ELS switch	a. Prepares ELS for automatic enabling during LES abort. b. Allows the ELS to function automatically during descent of C/M.		MESC logic bus through Z12 ELS activate relays	None	Normal position of switch.  Switch is set to the MAN position after drogue parachute deployment during an abort initiated prior to 61 seconds after lift-off. The main parachutes must be deployed manually with the MAIN DEPLOY pushbutton (MDC-5) after the switch is set to the MAN position. If the main parachutes are deployed manually, the MAIN DEPLOY-AUTO switch must be set back to AUTO to allow 14-second timer to enable parachute release after touchdown.
	AUTO	Disconnects logic arming circuitry from ELS controller.				
	MAN					

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MDC-16 (Cont)	ABORT SYSTEM switches					
	OX DUMP switch					
	AUTO	Enables circuitry through a 61-second timer to automatically dump the C/M RCS oxidizer during a pad or low-altitude abort prior to 61 seconds after lift-off.	MASTER EVENT SEQ CONT-A LOGIC B-BAT A BAT B (MDC-22)	Logic bus in the master event sequence controller	None	The 61-second timer, enabled by CM PROP JETT-LOGIC switch (MDC-8), starts at lift-off. The auto dump capability is disabled after the 61-seconds. Dump time is approximately 11 seconds.
	RCS CMD AUTO	Disables the auto oxidizer dump and allows the G&N/SCS system to be automatically enabled upon C/M-S/M separation to control the command module RCS during descent.				During normal ascent, the OX DUMP switch is moved to the RCS CMD AUTO position 61 seconds after lift-off.
	2 ENG OUT switch					
	AUTO	Activates the EDS for a two-engine out automatic abort capability by de-energizing the two-engine out auto abort deactivate relays.	None	L/V-IU batteries	L/V telemetry via IU	The two-engine out auto abort capability is also shut off automatically by the IU.
	OFF	Deactivates the EDS for a two-engine out automatic abort capability by energizing the two-engine out auto abort deactivate relays.				
	L/V RATES switch					
	AUTO	Activates the EDS for an excessive rates automatic abort capability by de-energizing the excessive rates auto abort deactivate relays.				
	OFF	Deactivates the EDS for an excessive rates automatic abort capability by energizing the excessive rates auto abort deactivate relays.				The excessive rates auto abort capability is also shut off automatically by the IU.

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MDC-16 (Cont)	MODE switches					The two switches are guarded.
	LES MODE	Enables systems A and B to use the launch escape system in case of an abort.	MASTER EVENT SEQ CONT - A LOGIC B - BAT A (MDC-22)	a. Battery buses A and B when the MESC LOGIC/OFF switch is in the LOGIC position b. EDS change over bus	None	After LET jettison, all aborts must be manually initiated and made in the SPS mode.
	TWR JETT SPS MODE	Initiates jettison of the LES tower and arms system A and B of the SPS abort circuitry.			CD0105X Tower jettison A CD0106X Tower jettison B	
	REACTION CONTROL SYS group					
	CMD switch		MASTER EVENT SEQ CONT - A ARM B BAT A BAT B (MDC-22)	Battery buses A and B		Three-position toggle switch, spring-loaded to the center position. Switch allows manual inhibit-enable of SCS inputs to the automatic coils of the C/M or S/M RCS engines.
	ON	Energizes latching relay, connecting SCS jet selection logic to RCS engines.				Inhibit-enable functions provide backup capability to MESC control of the RCS latching relay.
	Center	Enables MESC automatic control of latching relay.			None	Switch is momentarily set to ON after adapter separation. This function is accomplished automatically by the MESC 0.8 seconds after initiation of adapter separation with the ADAPT SEP pushbutton (MDC-5).
	OFF	De-energizes latching relay, disconnecting SCS jet selection logic from RCS engines.				If LES abort occurs after T + 61 seconds, the MESC automatically closes the relay 1 second after abort initiation. If an SPS abort occurs, the MESC automatically closes the relay 2.5 seconds after abort initiation.
						The MESC baroswitch input automatically causes the relay to open at approximately 24,000 feet during C/M descent.

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MDC-16 (Cont)	C/M PRESS switch Up Down	Activates helium isolation squib valves in both systems A and B. No function.	MASTER EVENT SEQ CONT - A ARM B BAT A BAT B (MDC-22)	Battery buses A and B	None	
	TRANS switch C/M	Energizes motor switch causing the following: a. Connects C/M RCS engines to SCS jet selection logic control circuits. b. Disables translation controls.	RCS-C/M - S/M TRANSFER MN A MN B (MDC-25)	D-C main buses A and B		Three-position switch, spring-loaded to the center position. Switch provides manual backup for automatic transfer function.
	Center S/M	Enables MESC automatic control of motor switch. Energizes motor switch, causing contacts to close which connect S/M RCS engines to SCS jet selection logic control circuits.				
	EDS switch AUTO OFF	Prepares the L/V EDS auto abort circuitry for automatic enabling at lift-off. All auto abort capabilities are disabled.	MASTER EVENT SEQ CONT - A LOGIC B- BAT A BAT B (MDC-22)	Battery buses A and B		Two-position toggle switch.
	MAIN CHUTE RELEASE switch Up Down	Releases the main parachutes from the command module. Disables the parachutes release circuitry.	MASTER EVENT SEQ CONT - A LOGIC B- BAT A BAT B (MDC-22)	MESC logic buses A and B	CE0321X CE0322X (Main chute disconnect relays A and B)	The switch is electrically enabled when the 10,000 feet baroswitch closes during descent and will release the parachutes when actuated. The switch should never be moved to the up (release) position until after landing impact. The switch is spring-loaded to the down position and guarded.

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MDC-18	MASTER ALARM switch-light	Red light illuminates to alert crewman in RH couch of a malfunction or out-of-tolerance condition. This is indicated by illumination of applicable system status lights on MDC-10 or -11.	CAUT/ WARN- MN A MN B (MDC-25)	D-C main buses A and B	CS0150X (Master caution-warning on)	MASTER ALARM lights on MDC-3, -18, and LEB-103 are simultaneously illuminated, and an audio alarm tone is sent to each headset.  The MASTER ALARM switch-light contains an integral push-switch. Pressing the switch-light will reset the master alarm circuit, extinguishing the MASTER ALARM lights and shutting off the audio alarm.
	pH HI event indicator  Striped-line display	Indicates pH factor of water from selected fuel cell is over 9, indicating a leakage of KOH electrolyte into the potable water supply.			SC2160Z (pH factor water condition F/C No. 1)  SC2161Z (pH factor water condition F/C No. 2)  SC2162Z (pH factor water condition F/C No. 3)	A pH factor of 7 designates pure water. (Water is potable with a pH factor below 9.) Fuel cell to be monitored is selected by FUEL CELL INDICATORS switch (MDC-18). The pH HI event indicator is part of the C&WS.
	Gray display	Indicates pH factor of water from selected fuel cell is below 9.				

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MDC-18 (Cont)	F/C RAD TEMP LOW event indicator		CAUT/ WARN- MN A MN B (MDC-25)	D-C main buses A and B	SC2087T (Temp F/C No. 1 radiator outlet)  SC2088T (Temp F/C No. 2 radiator outlet)  SC2089T (Temp F/C No. 3 radiator outlet)	Glycol operating range is -50° to +300°F. Fuel cell to be monitored is selected by FUEL CELL INDICATORS switch (MDC-18). The F/C RAD TEMP LOW event indicator is part of the C&WS.
	Striped-line display  Gray display	Indicates selected fuel cell glycol temperature at radiator outlet has dropped to -30°F or less.  Indicates selected fuel cell glycol temperature at radiator outlet is above -30°F.				
	FUEL CELL indicators  FLOW group  H <sub>2</sub> indicator	Indicates flow rate of H <sub>2</sub> into selected fuel cell.			SC2139R (Flow rate H <sub>2</sub> F/C No. 1)  SC2140R (Flow rate H <sub>2</sub> F/C No. 2)  SC2141R (Flow rate H <sub>2</sub> F/C No. 3)	Normal operating range (indicator green band) is 0.036 lb/hr to 0.163 lb/hr. Alarm limits to caution and warning system are 0.028 lb/hr lower, 0.153 lb/hr upper. Sensors for the indicator are located in the F/C H <sub>2</sub> inlet lines. Fuel cell to be monitored is selected by FUEL CELL INDICATORS switch (MDC-18).

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MDC-18 (Cont)	O <sub>2</sub> indicator	Indicates flow rate of O <sub>2</sub> into selected fuel cell.	CAUT/ WARN- MN A MN B (MDC-25)	D-C main buses A and B	SC2142R (Flow rate O <sub>2</sub> F/C No. 1)  SC2143R (Flow rate O <sub>2</sub> F/C No. 2)  SC2144R (Flow rate O <sub>2</sub> F/C No. 3)	Normal operating range (indicator green band) is 0.288 lb/hr to 1.304 lb/hr. Alarm limits to caution and warning system are 0.22 lb/hr lower, 1.22 lb/hr upper. Sensors for the indicator are located in the FUEL CELL O <sub>2</sub> inlet lines. Fuel cell to be monitored is selected by FUEL CELL INDICATORS switch (MDC-18).
	MODULE TEMP group  SKIN indicator	Indicates skin temperature of selected fuel cell.			SC2084T (Temp F/C No. 1 skin)  SC2085T (Temp F/C No. 2 skin)  SC2086T (Temp F/C No. 3 skin)	Normal indication is 385° to 500°F. Alarm limits to caution and warning system are 360°F lower, 500°F upper. Sensors for the indicator are located in the pressurized portion of the fuel cells. Fuel cell to be monitored is selected by FUEL CELL INDICATORS switch (MDC-18).
	COND EXH indicator	Indicates temperature of selected fuel cell condenser exhaust.			SC2081T (Temp F/C No. 1 cond exhaust)  SC2082T (Temp F/C No. 2 cond exhaust)  SC2083T (Temp F/C No. 3 cond exhaust)	Condenser exhaust operating range is 155°F to 175°F. Alarm limits to caution and warning system are 155°F to 175°F. Sensors for the indicator are located in the exhaust manifolds of the fuel cell condensers. Fuel cell to be monitored is selected by FUEL CELL INDICATORS switch (MDC-18).

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MDC-18 (Cont)	REG OUT PRESS HI event indicators		CAUT/ WARN- MN A MN B (MDC-25)	D-C main buses A and B	SC2069P (H <sub>2</sub> pressure F/C No. 1 regulated)  SC2070P (H <sub>2</sub> pressure F/C No. 2 regulated)  SC2071P (H <sub>2</sub> pressure F/C No. 3 regulated)	Fuel cell to be monitored is selected by FUEL CELL INDICATORS switch (MDC-18). The REG OUT PRESS HI event indicators are part of the C&WS.
	H <sub>2</sub> event indicators					Sensors for the indicator are located in the hydrogen pressure regulators.
	Striped-line display	Indicates when output pressure of H <sub>2</sub> regulator rises to 75 psia or greater on selected fuel cell.				
	Gray display	Indicates pressure is less than 75 psia.				Normal regulator output pressure is 61.5 psia.
	O <sub>2</sub> event indicator				SC2066P O <sub>2</sub> pressure F/C No. 1 regulated)  SC2067P O <sub>2</sub> pressure F/C No. 2 regulated)  SC2068P O <sub>2</sub> pressure F/C No. 3 regulated)	Sensors for the indicator are located in the F/C oxygen pressure regulators.
	Striped-line display	Indicates when output pressure of O <sub>2</sub> regulator rises to 75 psia or greater on selected fuel cell.				
		Indicates pressure is less than 75 psia.				Normal regulator output pressure is 63.5 psia.
	Gray display					

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MDC-18 (Cont)	N <sub>2</sub> event indicator Striped-line display Gray display	Indicates when output pressure of N <sub>2</sub> regulator rises to 70 psia or greater on selected fuel cell.  Indicates pressure is less than 70 psia.	CAUT/ WARN- MN A MN B (MDC-25)	D-C main buses A and B	SC2060P (N <sub>2</sub> pressure F/C No. 1 regulated)  SC2061P (N <sub>2</sub> pressure F/C No. 2 regulated)  SC2062P (N <sub>2</sub> pressure F/C No. 3 regulated)	Sensors for the indicator are located in the nitrogen pressure regulators.  Normal regulator output pressure is 53 psia.
	FUEL CELL switches Purge group Switches 1, 2 and 3 H <sub>2</sub> PURGE Center (off) O <sub>2</sub> PURGE	Accomplish purging of selected fuel cell.  Opens purge valve on H <sub>2</sub> side of selected fuel cell to purge impurities from H <sub>2</sub> electrodes.  Disconnects power from selected F/C O <sub>2</sub> or H <sub>2</sub> purge valve, closing valve (normal switch position).  Opens purge valve on O <sub>2</sub> side of selected fuel cell to purge impurities from O <sub>2</sub> electrodes.	FUEL CELL 1 - PURGE (MDC-22)  FUEL CELL 2 - PURGE (MDC-22)  FUEL CELL 3 - PURGE (MDC-22)		None	When purging the selected fuel cell, the C&WS will alarm if the reactants flow rate increases beyond the maximum normal flow rate. Purging (when operating at a 1420 w/fuel cell power level) is accomplished every 7 hours, alternating every 3-1/2 hours between O <sub>2</sub> and H <sub>2</sub> . O <sub>2</sub> purge time (switch ON) is 2 minutes and H <sub>2</sub> purge time (switch ON) is 80 seconds. O <sub>2</sub> and H <sub>2</sub> maximum flow rates during purge is 0.6 and 0.75 lb/hr above normal flow rates, respectively. Effect of purge can be monitored by FUEL CELL INDICATORS switch and DC INDICATORS switch and their associated displays.
	REACTANTS group	Provides ON - OFF control of reactant flow (H <sub>2</sub> and O <sub>2</sub> ) for selected fuel cells.				These switches control solenoid valves, which accomplish control of reactant flow.

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MDC-18 (Cont)	Switches 1, 2 and 3 ON	Momentary switch position connects d-c power to selected fuel cell O <sub>2</sub> and H <sub>2</sub> shutoff valve actuators, driving valves to open position.	FUEL CELL 1 - H <sub>2</sub> & O <sub>2</sub> VALVE (MDC-22)	Battery relay bus	SC2323X (Fuel cell No. 1 shutoff monitor)	Event indicators, located directly below their respective switches, display striped lines when both H <sub>2</sub> and O <sub>2</sub> shutoff valves are in closed (abnormal) position.
	(Center)	Valves remain in last selected position (normal switch position).	FUEL CELL 2 - H <sub>2</sub> & O <sub>2</sub> VALVE (MDC-22)		SC2324X (Fuel cell No. 2 shutoff monitor)	<b>Warning</b> Do not inadvertently position REACTANT switches OFF. Loss of fuel cell may result.
	OFF	Momentary switch position connects d-c power to selected fuel cell O <sub>2</sub> and H <sub>2</sub> shutoff valve actuators, driving valves to closed position.	FUEL CELL 3 - H <sub>2</sub> & O <sub>2</sub> VALVE (MDC-22)		SC2325X (Fuel cell No. 3 shutoff monitor)	
	Event Indicators 1, 2 and 3 Striped-line display Gray display	Indicates when H <sub>2</sub> and O <sub>2</sub> shutoff valves are closed on selected fuel cell. Indicates normal (open) position of valves.	FUEL CELL 1 - BUS CONT (MDC-22) FUEL CELL 2 - BUS CONT (MDC-22) FUEL CELL 3 - BUS CONT (MDC-22)		SC2323X (Fuel cell No. 1 shutoff monitor) SC2324X (Fuel cell No. 2 shutoff monitor) SC2325X (Fuel cell No. 3 shutoff monitor)	Event indicators function in conjunction with their respective switches located directly above.
MAIN BUS A group		Controls fuel cells No. 1, 2 and 3 electrical output to d-c main bus A. Momentary switch position connects electrical output of selected fuel cell to d-c main bus A. Connects C&W alarm and F/C - BUS DISCONNECT indicator light (MDC-11) to selected fuel cell motor switch (normal position of switch).	FUEL CELL 1 - BUS CONT (MDC-22) FUEL CELL 2 - BUS CONT (MDC-22) FUEL CELL 3 - BUS CONT (MDC-22)		SC2120X (Fuel cell No. 1 bus A disconnect) SC2121X (Fuel cell No. 2 bus A disconnect) SC2122X (Fuel cell No. 3 bus A disconnect)	When fuel cell main bus switches are placed to ON position, power is applied to a motor-driven switch located in an overload and reverse current sensing unit in the S/M. This accomplishes actual switching function required to apply output of selected fuel cell to d-c main bus A. Only one F/C BUS DISCONNECT status light (MDC-11) for all three F/C's.

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MDC-18 (Cont)	OFF	Disconnects electrical output of selected fuel cell from d-c main bus A.	FUEL CELL 1 - BUS CONT (MDC-22)  FUEL CELL 2 - BUS CONT (MDC-22)  FUEL CELL 3 - BUS CONT (MDC-22)	Battery relay bus	SC2120X (Fuel cell No. 1 bus A disconnect)  SC2121X (Fuel cell No. 2 bus A disconnect)  SC2122X (Fuel cell No. 3 bus A disconnect)	
	Reset switch	Provides capability of resetting d-c main bus A undervoltage protection circuit.	SNSR UNIT - DC BUS - A (MDC-21)		None	D-C main bus A undervoltage sensing circuit energizes MN BUS A UNDER-VOLT warning light (MDC-11) when d-c voltage drops below 26.25 vdc.
	RESET  (Center)	Momentary switch position resets d-c main bus A undervoltage sensing unit.  Connects MN BUS A UNDER-VOLT warning light to d-c bus A undervoltage sensing circuit.				
	OFF	Disconnects MN BUS A UNDER-VOLT warning light from d-c bus A undervoltage sensing circuit.				
	Event Indicators 1, 2 and 3		FUEL CELL 1 - BUS CONT (MDC-22)		SC2120X (Fuel cell No. 1 bus A disconnect)	Event indicators function in conjunction with their respective switches located directly above.
	Striped-line display	Indicates when selected F/C is removed from d-c main bus A.	FUEL CELL 2 - BUS CONT (MDC-22)		SC2121X (Fuel cell No. 2 bus A disconnect)	
	Gray display	Indicates selected F/C is connected to bus.	FUEL CELL 3 - BUS CONT (MDC-22)		SC2122X (Fuel cell No. 3 bus A disconnect)	

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MDC-18 (Cont)	MAIN BUS B group  Switches 1, 2 and 3  ON  (Center)  OFF	Controls fuel cells No. 1, 2 and 3 electrical output to d-c main bus B.	FUEL CELL 1 - BUS CONT (MDC-22)	Battery relay bus	SC2125X (Fuel cell No. 1 bus B disconnect)	When fuel cell main bus switches are placed to ON position, power is applied to a motor-driven switch located in an overload and reverse current sensing unit in the S/M. This accomplishes actual switching function required to apply output of selected fuel cell to d-c main bus B. Only on F/C BUS DISCONNECT status light (MDC-11) for all three fuel cells.
		Momentary switch position connects electrical output of selected fuel cell to d-c main bus B.	FUEL CELL 2 - BUS CONT (MDC-22)		SC2126X (Fuel cell No. 2 bus B disconnect)	
		Connects G&W alarm and F/C BUS DISCONNECT indicator light (MDC-11) to selected fuel cell motor switch (normal position of switch).	FUEL CELL 3 - BUS CONT (MDC-22)		SC2127X (Fuel cell No. 3 bus B disconnect)	
		Disconnects electrical output of selected fuel cell from d-c main bus B.				
	Reset Switch  RESET  (Center)  OFF	Provides capability of resetting d-c main bus B undervoltage protection circuit.	SNRS UNIT - DC BUS - B (MDC-21)		None	D-C main bus B undervoltage sensing circuit energizes MN BUS B UNDER-VOLT warning light (MDC-11) when d-c voltage drops below 26.25 vdc.
		Momentary switch position resets d-c main bus B undervoltage sensing circuit.				
		Connects MN BUS B UNDER-VOLT warning light to d-c bus B undervoltage sensing circuit.				
		Disconnects MN BUS B UNDER-VOLT warning from d-c bus B undervoltage sensing circuit.				
	Event Indicators 1, 2 and 3)  Striped-line display  Gray display	Indicates when selected fuel cell is removed from d-c main bus B.	FUEL CELL 1 - BUS CONT (MDC-22)		SC2125X (Fuel cell No. 1 bus B disconnect)	Event indicators function in conjunction with their respective switches located directly above.
		Indicates selected fuel cell is connected to bus.	FUEL CELL 2 - BUS CONT (MDC-22)			
			FUEL CELL 3 - BUS CONT (MDC-22)		SC2126X (Fuel cell No. 2 bus B disconnect)	
					SC2127X (Fuel cell No. 3 bus B disconnect)	

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MDC-18 (Cont)	FUEL CELL INDICATORS switch	Selects desired fuel cell to be monitored by the fuel cell display indicators.		Dependent on position (insignificant)	None	Indicators associated with switch are as follows: a. FLOW indicators H <sub>2</sub> and O <sub>2</sub> b. MODULE TEMP indicators SKIN and CONDEXH c. REG OUT PRESS HI - O <sub>2</sub> d. REG OUT PRESS HI - H <sub>2</sub> e. REG OUT PRESS HI - N <sub>2</sub> f. pH HI g. F/C RAD TEMP LOW.
	1	Applies selected outputs of fuel cell No. 1 to fuel cell display indicators.				
	2	Applies selected outputs of fuel cell No. 2 to fuel cell display indicators.				
	3	Applies selected outputs of fuel cell No. 3 to fuel cell display indicators.				<b>NOTE</b> Items a and b are analog signals. Items c through g are ON-OFF signals (event indicators).
	BATTERY CHARGER switch	Controls a-c and d-c power to battery charger, and selects battery to be charged.  Disconnects electrical power from battery charger.	BATTERY CHARGER-MN A MN B AC PWR (MDC-22)	D-C main bus A and B and a-c bus No. 1 or No. 2	CC0214V (D-C voltage bat charger out)  CC0215C (D-C current bat charger out)	Switch actuates battery charger input-power control relay, routing a-c and d-c voltages through relay contacts to battery charger. Current flow is negligible when a battery is fully charged. MAIN BUS TIE switches (MDC-22) for selected battery must be off before a battery can be charged. A-C power for the battery charger is selected from a-c bus No. 1 or a-c bus No. 2 by the BAT CHGR switch (MDC-22).
	OFF					
	A	Controls a-c and d-c power to battery charger and routes output of battery charger to entry battery A.				
	B	Controls a-c and d-c power to battery charger and routes output of battery charger to entry battery B.				
	C	Controls a-c and d-c power to battery charger and routes output of battery charger to post-landing battery C.				
	SUIT PACK	No function.				

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MDC-18 (Cont)	DC VOLTS meter	Indicates d-c voltage of selected source, unit, or bus.		As selected by DC INDICATORS switch.	Refer to DC INDICATORS switch.	Meter functions in conjunction with DC INDICATORS switch. DC VOLTS meter range is 20 to 45 vdc.
	DC AMPS meter	Indicates d-c current of selected source, unit, or bus.				Meter functions in conjunction with DC INDICATORS switch. DC AMPS meter range is 0 to 100 amperes, 0 to 5 amperes expanded scale battery charger output.
	DC INDICATORS switch	Selects power source, bus, or unit to be monitored by DC VOLT and DC AMPS meters.				In some cases, only current or voltage is indicated by DC VOLTS and DC AMPS meters. In other cases, both voltage and current are indicated. These are listed in the function column associated with each position. The DC VOLTS meter will read slightly below 20 vdc when not in use. The DC AMPS meter will read zero amperes when not connected to a load.
	FUEL CELL - 1	Applies output of fuel cell No. 1 shunt to DC AMPS meter.		Fuel cell No. 1	SC2113C (D-C current F/C No. 1 output)	
	FUEL CELL - 2	Applies output of fuel cell No. 2 shunt to DC AMPS meter.		Fuel cell No. 2	SC2114C (D-C current F/C No. 2 output)	
	FUEL CELL - 3	Applies output of fuel cell No. 3 shunt to DC AMPS meter.		Fuel cell No. 3	SC2115C (D-C current F/C No. 3 output)	
	MAIN BUS - A	Applies voltage of d-c main bus A to DC VOLTS meter.	SNSR UNIT - DC BUS - A (MDC-21)	D-C main bus A	CC0206V (D-C voltage main bus A)	
	MAIN BUS - B	Applies voltage of d-c main bus B to DC VOLTS meter.	SNSR UNIT - DC BUS - B (MDC-21)	D-C main bus B	CC0207V (D-C voltage main bus B)	
	BAT BUS - A	Applies both voltage and current of battery bus A to DC VOLTS and DC AMPS meters.		Battery bus A	CC0210V (D-C voltage battery bus A)	MASTER EVENT SEQ CONT-LOGIC-BAT A c/b (MDC-22) controls d-c voltage indication (voltage only) and measurement for telemetry.
					CC0222C (D-C current battery A)	

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MDC-18 (Cont)	BAT BUS -B	Applies both voltage and current of battery bus B to DC VOLTS and DC AMPS meters.		Battery bus B	CC0211V (D-C voltage battery bus B)	MASTER EVENT SEQ CONT-LOGIC-BAT B c/b (MDC-22) controls d-c voltage indication (voltage only) and measurement for telemetry.
	BAT CHARGER	Applies both voltage and current output of battery charger to DC VOLT and DC AMPS meter (inner scale 0 to 5 amps).		Battery charger	CC0223C (D-C current battery B)	Charger current output will be according to charge required by battery (up to 2.5 amps).
	BAT C	Applies both voltage and current outputs of battery C to DC VOLTS and DC AMPS meters.	BAT CHGR BAT C (LEB-150)	Battery C	CC0214V (D-C voltage battery charger out)  CC0215C (D-C current battery charger out)	Listed C/B will control d-c voltage indication and measurement for telemetry.
	PYRO BAT-A	Applies pyro battery A voltage to DC VOLTS meter when SEQ A cb is closed.	PYRO A - SEQ A	Pyro battery A	CC0212V (D-C voltage post-landing battery)	Normally closed cb. Open circuit minimal voltage of 37.2 vdc will be read on meter.
		Applies entry battery A voltage to DC VOLTS meter when BAT A to PYRO BUS TIE cb is closed.	BAT A TO PYRO BUS TIE	Entry battery A	CC0224C (D-C current post-landing battery)	Normally open cb. Open circuit nominal voltage of 37.2 vdc, or load voltage of 28 vdc will be read on meter.
	PYRO BAT-B	Applies pyro battery B voltage to DC VOLTS meter when SEQ B cb is closed.	PYRO B - SEQ B	Pyro battery B		Normally closed cb. Open circuit nominal voltage of 37.2 vdc will be read on meter.
		Applies entry battery B voltage to DC VOLTS meter when BAT B to PYRO BUS TIE cb is closed.	BAT B TO PYRO BUS TIE	Entry battery B		Normally closed cb. Open circuit nominal voltage of 37.2 vdc, or load voltage of 28 vdc will be read on meter.
	AC INVERTER switches				Refer to AC INDICATORS switches (MDC-18)	Interlocking circuitry between AC INVERTER-AC BUS 1 and AC BUS 2 prevents more than one inverter from being connected to any one bus at the same time.

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MDC-18 (Cont)	Switch 1	Controls d-c power to a-c inverter No. 1 by actuating a motor-driven switch which accomplishes actual switching function.	INVERTER CONTROL - 1 (MDC-22)	Battery relay bus	Refer to AC INDICATORS switch	Circuit breakers associated with delivering power to AC INVERTER No. 1 from d-c main bus A is INVERTER PWR - No. 1 - MN A on main circuit breaker panel (RHEB-203).
	MN A	Applies d-c power to a-c inverter No. 1.				
	OFF	Disconnects d-c power from a-c inverter No. 1.				
	Switch 2	Controls d-c power to a-c inverter No. 2 by actuating a motor-driven switch which accomplishes actual switching function.	INVERTER CONTROL - 2 (MDC-22)			Circuit breaker associated with delivering power to AC INVERTER No. 2 from d-c main bus B is INVERTER PWR - No. 2 - MN B on main circuit breaker panel (RHEB-203).
	MN B	Applies d-c power to a-c inverter No. 2.				
	OFF	Disconnects d-c power from a-c inverter No. 2.				
	Switch 3	Controls d-c power to a-c inverter No. 3 by actuating one of two motor-driven switches depending on bus selected.	INVERTER CONTROL - 3 (MDC-22)			Inverter No. 3 can receive power from either d-c main bus A or d-c main bus B. Associated circuit breakers are INVERTER PWR - No. 3 - MN A and - MN B (RHEB-203).
	MN A	Applies d-c power from main bus A to a-c inverter No. 3.				
	OFF	Disconnects d-c power from a-c inverter No. 3.				
	MN B	Applies d-c power from main bus B to a-c inverter No. 3.				
AC BUS 1 group	Switch 1	Controls a-c output of inverter No. 1 to a-c bus No. 1	INVERTER CONTROL - 1 (MDC-22)			Actuates a motor-driven switch which accomplishes actual switching function.
	ON	Applies a-c output of inverter No. 1 to a-c bus No. 1				
	OFF	Disconnects a-c output of inverter No. 1 from a-c bus No. 1.				

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MDC-18 (Cont)	Switch 2	Controls a-c output of inverter No. 2 to a-c bus No. 1.	INVERTER CONTROL - 2 (MDC-22)	Battery relay bus	Refer to AC INDICA-TORS switch		
	ON	Applies a-c output of inverter No. 2 to a-c bus No. 1.					
	OFF	Disconnects a-c output of inverter No. 2 from a-c bus No. 1.					
	Switch 3	Controls a-c output of inverter No. 3 to a-c bus No. 1.	INVERTER CONTROL - 3 (MDC-22)				
	ON	Applies a-c output of inverter No. 3 to a-c bus No. 1.					
	OFF	Disconnects a-c output of inverter No. 3 to a-c bus No. 1.					
	RESET/OFF switch	Provides capability of resetting a-c bus No. 1 over undervoltage and overload sensing unit. Also releases relay which reconnects the operating inverter to a-c bus No. 1, if it had been tripped off due to overvoltage or overload.	SNSR UNIT - AC BUS - 1 (MDC-21)		None	Resetting a-c bus 1 over-undervoltage and overload sensing unit also turns AC BUS 1 FAIL and AC BUS 1 OVERLOAD caution and warning lights off. Circuit breaker associated with the a-c sensing lines on a-c bus No. 1 is AC SNSR SIG - AC1 (MDC-25).	
	RESET	Momentary position resets a-c bus No. 1 over-undervoltage and overload sensing unit.					
	(Center)	Energizes a-c bus No. 1 over-undervoltage and overload sensing unit.					
	OFF	Disconnects a-c bus No. 1 over-undervoltage and overload sensing unit from system.	INVERTER CONTROL - 1 (MDC-22)		Refer to AC INDICA-TORS switch	Actuates a motor-driven switch which accomplishes actual switching function.	
	AC BUS 2 group	Controls output of inverter No. 1 to a-c bus No. 2.					
	Switch 1	Applies output of inverter No. 1 to a-c bus No. 2.					
	ON	Applies output of inverter No. 1 to a-c bus No. 2.					
	OFF	Disconnects output of inverter No. 1 from a-c bus No. 2.					

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MDC-18 (Cont)	Switch 2	Controls output of inverter No. 2 to a-c bus No. 2.	INVERTER CONTROL - 2 (MDC-22)	Battery relay bus	Refer to AC INDICATORS switch	
	ON	Applies output of inverter No. 2 to a-c bus No. 2.				
	OFF	Disconnects output of inverter No. 2 from a-c bus No. 2.				
	Switch 3	Controls output of inverter No. 3 to a-c bus No. 2.	INVERTER CONTROL - 3 (MDC-22)			
	ON	Applies output of inverter No. 3 to a-c bus No. 2.				
	OFF	Disconnects output of inverter No. 3 from a-c bus No. 2.				
	RESET/OFF switch	Provides capability of resetting a-c bus No. 2 over-undervoltage and overload sensing unit. Also releases relay which reconnects the operating inverter to a-c bus No. 2 if it has been tripped off due to over-voltage or overload.	SNSR UNIT - AC BUS - 2 (MDC-21)		None	Resetting a-c bus No. 2 over-undervoltage and overload sensing unit also turns AC BUS 2 FAIL and AC BUS 2 OVERLOAD caution and warning lights (MDC-11) ON. Circuit breaker associated with sensing lines on a-c bus No. 2 is AC SNSR SIG - AC2 (MDC-25).
	RESET	Resets a-c bus No. 2 over-undervoltage and overload sensing unit.				
	(Center)	Energizes a-c bus No. 2 over-undervoltage and overload sensing unit.				
	OFF	Disconnects a-c bus No. 2 over-undervoltage and overload sensing unit from the system.				
	AC VOLTS meter	Indicates a-c voltage of selected source and phase.	AC SNSR SIG - AC 1 AC 2 (MDC-25)	As selected by AC INDICATORS switch	Refer to AC INDICATORS switch	Meter functions in conjunction with AC INDICATORS switch. AC VOLTS meter range is 90 to 130 vac.
	FREQ GP'S meter	Indicates frequency of selected source and phase.				FREQ GP'S meter range is 380 to 420 cps.
	AC INDICATORS switch	Provides means of monitoring 3Ø voltage and frequency output of a-c inverters.				Operating range for phase A, B, and C (a-c bus No. 1 or a-c bus No. 2) is 115 ±2 vac 400 cps, during emergency mode 393 to 407 cps. Only phase A frequency measurement of a-c buses 1 and 2 are telemetered to MSFN ground stations.

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MDC-18 (Cont)	BUS 1 group ØA	Applies a-c phase A voltage from a-c bus No. 1 to AC VOLTS and FREQUENCY meters.	AC SNSR SIG - AC1 (MDC-25)	A-C bus No. 1	CC0200V (A-C voltage main bus 1 phase A)	
		Applies a-c phase B voltage from a-c bus No. 1 to AC VOLTS and FREQUENCY meters.			CC0213F (Frequency a-c bus 1 phase A)	
		Applies a-c phase C voltage from a-c bus No. 1 to AC VOLTS and FREQUENCY meters.			CC0201V (A-C voltage main bus 1 phase B)	
	BUS 2 group ØA	Applies a-c phase A voltage from a-c bus No. 2 to AC VOLTS and FREQUENCY meters.	AC SNSR SIG - AC2 (MDC-25)	A-C bus No. 2	CC0203V (A-C voltage main bus 2 phase A)	
		Applies a-c phase B voltage from a-c bus No. 2 to AC VOLTS and FREQUENCY meters.			CC0217F (Frequency a-c bus 2 phase A)	
		Applies a-c phase C voltage from a-c bus No. 2 to AC VOLTS and FREQUENCY meters.			CC0204V (A-C voltage main bus 2 phase B)	
	ØC				CC0205V (A-C voltage main bus No. 2 phase C)	

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-19	ECS RAD OUT TEMP-1 indicator	Provides temperature indication of water-glycol at outlet of 6-tube circuit of radiator 1 (S/M sector V).	INSTRUMENT- NONESSEN- TIAL (MDC-22) also NONESSEN- TIAL -9 (RHEB-204)	NONESSEN- TIAL BUS No. 1 (D-C main buses A or B)	SF0671T (Tank ECS radiator outlet 1)	Sensors located in outlet lines of radiators 1A and 2A on S/M forward bulkhead.  Normal radiator outlet temperatures should not decrease below 30°F.
	ECS RAD OUT TEMP-2	Provides temperature indication of water-glycol at outlet of 6-tube circuit of radiator 2 (S/M sector II).			SF0672T (Tank ECS radiator outlet 2)	
	S-BAND ANT indicator	Indicates relative strength of signal being received by USBE.	N/A	USBE	CT0147V (S-Band RCVR AGC voltage)	Signal strength meter that operates off of voltage obtained from AGC circuitry in USBE. No calibration, tune for maximum signal by switching S-band antennas or rotating S/C for optimum reception.
	UP TLM CMD switch RESET	Applies 28 vdc to the reset windings of all real-time command relays in the UDL RTC relay box. This cancels any real-time commands previously received via the UDL and returns control to the S/C.	T/C- GROUP 5 (MDC-22)	Flight and postlanding bus	None	DPDT switch, spring-loaded in the OFF position.
	FLIGHT QUAL RCDR switch RECORD	Activates FQR electronic circuits and tape transport mechanism to record flight qualification data. Tape moves in forward direction at 15 IPS.	RCDR NON ESS (MDC-22)	FQR (Refer to Remarks.)	CT0013X (Tape motion monitor R&D)	Power to the switch is provided by the FQR control logic. The non-essential bus supplies 28-vdc power to the FQR through the RCDR NON ESS circuit breaker (MDC-22). Three-phase a-c power from the TELCOM-NON ESS switch is supplied to the FQR through the T/C - GROUP 1 AC circuit breaker (MDC-22).
	F/C VALVES RESET  OFF	Provides +28 vdc to motor switch to disconnect holding voltage applied to the open solenoids of F/C 1, 2, and 3 reactant shutoff valves.  Normal position of switch.	FUEL CELL 1 H <sub>2</sub> and O <sub>2</sub> VALVE and FUEL CELL 2 H <sub>2</sub> and O <sub>2</sub> VALVE (MDC-22)	BATTERY RELAY BUS	None	Switch operated to momentary RESET position only after earth orbit insertion.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-19 (Cont)	STOP	Remove power from FQR electronic circuits and tape transport mechanism. Tape is locked in place.	FUEL CELL 1 H <sub>2</sub> and O <sub>2</sub> VALVE and FUEL CELL 2 H <sub>2</sub> and O <sub>2</sub> VALVE (MDC-22)	BATTERY RELAY BUS	None	NOTE The total record time for the FQR is 30 minutes. Since there are no dumping capabilities, the FQR must be used conservatively.  The rewind function is provided to allow the crewman to back the tape up to the beginning in case a launch hold occurs after the tape has begun to run or inadvertently left in RECORD. MSFN will direct time of rewind.
	REWIND	Activates FQR tape transport mechanism to rewind tape. Tape moves in reverse direction at 120 IPS.				
	VOICE RECORD event indicator		RCDR NON ESS (MDC-22)	DC NON ESS BUS No. 1		Visible when not recording or when tape supply is exhausted.  Recording in progress.
	Gray area  Striped area	Voice recorder inactive  Voice recorder tape is in motion.				
	F/C VALVES switch  RESET  (Down)	Momentary switch position actuates motor switch to remove holding voltage from open side of all F/C reactant valves.  Normal switch position disconnects power to motor switch.	FUEL CELL 1-H <sub>2</sub> &O <sub>2</sub> VALVE (MDC-22)  FUEL CELL 2-H <sub>2</sub> &O <sub>2</sub> VALVE (MDC-22)	Battery Relay Bus	None	Motor switch activated by GSE, provides open side of all F/C reactant valves with holding voltage to prevent inadvertent closing of reactant valves during launch, ascent, and orbital insertion.  NOTE To shut down a fuel cell when holding voltage is still applied to F/C reactant valves, F/C VALVES switch must be reset prior to closing F/C reactant valves.  Once the F/C reactant valves holding voltage is removed, F/C VALVES switch is inoperative.
	SPS LINE HEATER switch  A          OFF	Provides power to the 26 electrical system A or B element strip heaters on the tank feed and engine feed line brackets and the injector valve assembly. Switch would be placed to A if the propellant temperature indicator on panel 20 indicated -40°F (propellant temperature equivalent to +40°F).  Removes power from electrical system A or B element strip heaters. Switch placed to OFF when propellant temperature indicator on panel 20 indicated +80°F (equivalent to propellant temperature of +120°F).	SPS GAUG- ING MN A MN B (MDC-25)	D-C MAIN BUS A and B	None	The SPS HEATER switch provides power to the SPS electrical strip heaters mounted on the tank feed and engine feed line, brackets, and the injector valve assembly of the engine. The SPS HEATER switch will enable power to 26 electrical system A element strip heaters or will enable power to the 26 electrical system B element strip heaters, which will provide temperature control to the SPS engine compartment, thus the propellants.

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MDC-19 (Cont)	B	Provides power to the 26 electrical system B element strip heaters on the tank feed and engine feed line brackets and the injector valve assembly. If switch was not placed to A, would be placed to B when the propellant temperature indicator on panel 20 is at -40°F (equivalent to +40°F propellant temperature).	SPS GAUG- ING MN A MN B (MDC-25)	D-C MAIN BUS A and B	None	

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20	S-BAND switches	<p>Activates USBE, with or without S-band PA, and PMP circuitry which is required for S-band operations.</p> <p>a. De-energizes holding relay K2 in circuit utilization box which:</p> <ol style="list-style-type: none"> <li>1. Applies 3-phase a-c power from the T/C - GROUP 2 AC circuit breaker to the USBE power supply</li> <li>2. Applies 28-vdc power from the T/C - GROUP 5 circuit breaker to the 20 VDC voltage regulator in the PMP. (Refer to Remarks.)</li> </ol> <p>b. Applies 28-vdc power to the S-BAND ANTENNA switch.</p> <p>a. Energizes holding relay K2 in circuit utilization box which removes power from circuits described in Function a, XPONDER position.</p> <p>b. Removes 28-vdc power from the S-BAND ANTENNA switch</p> <p>a. (Same as for XPONDER position, Function a.)</p> <p>b. (Same as for XPONDER position, Function b.)</p> <p>c. Energizes relay K1 in circuit utilization box which applies 3-phase a-c power from the T/C - SIG COND S-BAND PA AC circuit breaker (MDC-22) to the S-BAND PA.</p>	T/C - GROUP 5 (MDC-22)	Flight and postlanding bus	None	<p>This position can be selected to conserve power if S-band communications are good enough to permit operations without the S-band PA equipment.</p> <p>The 20 vdc regulator in the PMP supplies power to those circuits in the PMP which are required for S-band emergency voice, emergency key, and UDL operations.</p> <p>This position will normally be selected for S-band communications to ensure adequate strength of transmitted signal. After selecting this position, a 90-second delay occurs to allow for warmup before application of B+ and switching of RF signal to the PA.</p>
	XPONDER					
	OFF					
	XPONDER PWR AMPL					

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20 (Cont)	PWR AMPL switch		N/A	S-band PA internal circuitry	None	Supplies ground for S-band PA control relays. Effective only when S-BAND-XPONDER/OFF/XPONDER PWR AMPL switch is in XPONDER PWR AMPL position.
	HIGH	Selects high-power (20-watt) output mode of S-BAND PA.				
	LOW	Selects low-power (5-watt) output mode of S-BAND PA.				
	OSC switch			USBE		Supplies ground for USBE control circuitry.
	PRIM	Selects primary oscillator frequency for USBE transmitter. It is obtained from USBE receiver VCO that is controlled by frequency of received S-band carrier to ensure doppler accuracy.				The primary oscillator is selected for all S-band operations unless USBE receiver has a malfunction.
	SEC	Selects secondary oscillator frequency for USBE transmitter. It is obtained from a crystal-controlled auxiliary oscillator.				The S-BAND-VOICE-RNG/RNG ONLY switch must also be in the off (center) position to enable selection of the secondary oscillator. (The secondary oscillator will be selected automatically when ever the S-BAND-EMER switch is set to VOICE.)
	VOICE group	Used to determine USBE/PMP mode and select data to be transmitted via S-band carrier. Only one of the three switches may be moved from the OFF (center) position at any one time. With all three switches at the OFF (center) position the USBE will transmit real-time voice and PCM data in a PM mode.				Three DP3T switches; one pole of each is used to control PMP circuits; the other pole is used to control USBE circuits.
	RNG/RNG ONLY switch					Voice transmission controlled by cobra cable PTT pushbutton when audio centers (MDC-13, -23, -26) POWER switch is at either PTT or VOX. Cobra cable PTT/CW switches must be at PTT.
	RNG	Enables PM transmission of received PRN ranging code in addition to real-time voice and PCM data.		USBE and PMP internal circuitry (Refer to Remarks.)		Supplies ground returns for USBE and PMP control circuits.
	Off (center)	(Refer to VOICE group Function.)				Closes a diode switch in the USBE transmitter which allows the PRN ranging signal from the USBE receiver to be modulated in the PM circuit.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20 (Cont)	RNG ONLY	Enables PM transmission of received PRN ranging code and real-time voice. PCM data is eliminated to reduce bandwidth and increase range.	N/A	USBE and PMP internal circuitry (Refer to Remarks.)	None	Removes power from PCM processing circuits in PMP.
	TAPE switch	Enables FM transmission of real-time voice and stored PCM and/or analog data, as follows: a. Supplies 28-vdc control power to TAPE RECORDER - PLAY switch (MDC-20). b. Selects FM output mode of PMP. c. Selects FM transmission mode of USBE. (Refer to VOICE group Function.)				One pole of this switch supplies ground for USBE control circuits. The other pole supplies 28-vdc control power obtained from the PMP power supply to PMP control circuits.  Refer to TAPE RECORDER - PLAY switch (MDC-20) Function and Remarks for further discussion of recorded data transmission capabilities.
	Off (center)					

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MDC-20 (Cont)	TV switch		N/A	USBE and PMP internal circuitry (Refer to Remarks.)	None	One pole of this switch supplies ground for USBE control circuits. The other pole supplies 28-vdc control power obtained from the PMP power supply to PMP control circuits.
	IV  Off (center)	Enables FM transmission of real-time video data from the TV camera along with real-time voice and PCM data, as follows: a. Closes diode switch in PMP to pass video signal to FM mixer. b. Selects FM output mode of PMP. c. Selects FM transmission mode of USBE (Refer to VOICE group Function.)				ON/OFF slide switch on TV camera handle must also be set to ON.
	EMERG switch	Enables transmission of voice or CW code over the S-band carrier with nonessential PMP circuitry disabled.	T/C - GROUP 5 (MDC-22)	Flight and postlanding bus and USBE internal circuitry		Switch applies 28-vdc control power to PMP circuits; supplies ground for USBE circuits.
	VOICE	Enables FM transmission of real-time voice only, as follows: a. Activates a-c power control relay in PMP, turning off 28-vdc power supply that supplies power to non-essential PMP circuits. b. Deactivates voice control relay in PMP, allowing voice signal from audio center equipment to bypass PMP voice processing circuits and go directly to USBE. c. Selects auxiliary oscillator and FM transmission mode in USBE. (Voice signal is applied directly to the auxiliary oscillator.)				Voice transmission possible when audio center (MDC-13, -23, or -26) POWER switch is at either PTT or VOX and cobra cable PTT push-button pressed, cobra cable PTT / CW switch must be at PTT.

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MDC-20 (Cont)	Off (center)  KEY	Allows normal USBE and PMP operation. Enables PM transmission of CW code, as follows: a. Activates a-c power control relay in PMP, turning off 28-vdc power supply that supplies power to non-essential PMP circuits. b. Applies 28-vdc power to emergency key circuitry in PMP. c. Selects PM transmission mode in USBE. Either the primary or secondary (auxiliary) oscillator frequency may be used.	T/C - GROUP 5 (MDC-22)	Flight and postlanding bus and USBE internal circuitry	None	Keying of transmitted CW code is accomplished by pressing the PTT pushbutton on cobra cables. (The cobra cable PTT/CW toggle switch must be set to CW.)
	Up-DATA switch  S-BAND  Off (center)  UHF	Activates UDL equipment in S-band mode by applying 28-vdc power to UDL power supply only (UHF/FM receiver portion of UDL equipment is disabled).  Removes power from UDL equipment.  Activates UDL equipment in UHF mode by applying 28-vdc power to UDL power supply, UHF/FM receiver, and mode switch, all contained in UDL equipment.		Flight and postlanding bus		Reception of up-data from the MSFN in the S-band mode is via the USBE receiver and PMP up-data discriminator.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20 (Cont)	S-BAND ANTENNA switch	Applies 28-vdc control power to 2-KMC antenna switch, either directly or via the USBE threshold selector (when in AUTO position).	N/A	S-BAND - XPONDER/OFF/XPONDER PWR AMPL switch (MDC-20)	None	The 28-vdc power is supplied to the S-BAND ANTENNA switch when the S-BAND-XPONDER/OFF/XPONDER PWR AMPL switch (MDC-20) is in the XPONDER or XPONDER PWR AMPL position. This power comes from the flight and postlanding bus via the T/C-GROUP 5 circuit breaker (MDC-22).
	AUTO	Permits automatic selection of SCIN antenna for S-band transmission and reception.				When in automatic mode, selection is made by a threshold selector in the USBE. Selection is based on strength of received signal.
	UPPER	Selects the upper (-Z) SCIN antenna for S-band transmission and reception.				Upper or lower antenna selected manually. S-BAND ANTENNA meter (MDC-19) indicates received signal strength at selected antenna.
	LOWER	Selects the lower (+Z) SCIN antenna for S-band transmission and reception.				
	VHF-AM controls	SQUELCH control Rotated upward or downward as required		VHF/AM transmitter-receiver internal circuitry		Squelch gate sensitivity determines strength of received signal that is required to permit detected audio to pass to audio center equipment.
	T/R/OFF/REC switch		T/C - GROUP 4 (MDC-22)	Flight and postlanding bus		In the T/R mode the transmitter operates in standby with filaments lit; B+ is not applied until keying occurs by closing PTT pushbutton on cobra cable when PTT/CW switch is at PTT.
	T/R	Applies power to transmitter and receiver circuitry in VHF/AM transmitter-receiver.				
	OFF	Removes power from VHF/AM transmitter-receiver.				
	REC	Applies power to receiver circuitry only in VHF/AM transmitter-receiver.				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20 (Cont)	RCVR switch	Selects VHF/AM receive frequency No. 1 (296.8 mc).	N/A	VHF/AM transmitter-receiver internal circuitry	None	Receive 1 frequency is used for simplex communications.
	2	Selects VHF/AM receive frequency No. 2 (259.7 mc).				Receive 2 frequency is used for duplex communications.
	C-BAND switch	Activates C-band transponder in 1-pulse mode, as follows: a. Activates holding relay K3 in circuit utilization box which applies 3-phase a-c power from T/C - GROUP 1 AC circuit breaker (MDC-22) to C-band transponder power supply. b. Applies control to decoder circuit to select 2-pulse mode.	T/C - GROUP 5 (MDC-22)	Flight and postlanding bus		The 1 PULSE mode is selected only when C-band tracking is required by a MSFN station having no capability for 2-pulse operations. One-pulse mode will be responsive to a 1- or 2-pulse MSFN station. One-pulse operation may be changed by UDL to 2-pulse mode.
	Off (center)  2 PULSE	Deactivates C-band transponder equipment.  Activates C-band transponder in 2-pulse mode, as follows: a. Activates holding relay K3 in circuit utilization box which applies 3-phase a-c power from T/C - GROUP 1 AC circuit breaker (MDC-22) to C-band transponder power supply. b. Applies control to decoder circuit to select 2-pulse mode.				UDL may turn on C-band in 2-pulse mode.  The 2-pulse mode is selected for launch and when C-band tracking is required by MSFN stations having capability for 2-pulse operation. Activation of the C-band transponder in the 2-pulse mode can also be commanded by MSFN by a UDL real-time command.
	VHF-FM switch	Activates VHF/FM transmitter by energizing a relay that applies 3-phase a-c power from the T/C - GROUP 1 AC circuit breaker (MDC-22) to its power supply.  Deactivates VHF/FM transmitter.				The VHF/FM transmitter is the primary means for transmitting PCM TLM, real time or stored. Activation of the VHF/FM transmitter can also be commanded by the MSFN by a UDL real-time command. This command occurs simultaneously with a command to the PCM TLM equipment for high bit-rate PCM.
	ON					
	OFF					

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MDC-20 (Cont)	RECOVERY switches					
	VHF-BCN switch					
	ON	Applies 28-vdc power to activate VHF recovery beacon.	T/C - GROUP 3 (MDC-22)	Flight and postlanding bus	None	A CW signal is transmitted at 3-second intervals for a period of 2 seconds (2 seconds on, 3 seconds off). Activate following dereefing of main parachutes.
	OFF	Removes 28-vdc power from VHF recovery beacon.				
	HF group					
	ON/OFF switch					
	ON	Activates HF transceiver, as follows: a. Applies 28-vdc power to receiver and oscillator circuits b. Applies 28-vdc control power to transmitter and antenna switching relays. (Refer to Remarks.)	T/C - GROUP 4 (MDC-22)			Activate following deployment of HF recovery antenna.  The transmitter keying relay controls application of 28-vdc power to transmitter circuits. The antenna switching relay disconnects antenna from receiver input and connects it to transmitter output. This provides for simplex HF operation. These relays will not energize until a ground return path is provided by keying the transmitter or selecting the beacon mode of operation.
	OFF	Deactivates HF transceiver.				
	SSB/BCN/AM switch					
	SSB	Selects SSB mode of HF transceiver.	N/A			Supplies ground for mode control circuits.
	BCN	a. Selects BCN mode of HF transceiver. b. Provides ground to voice recorder power control relay				In the BCN mode, the HF transceiver emits a continuous unmodulated carrier. This mode will also energize the voice recorder power control relay, circumventing the normal VOX control.
	AM	Selects AM mode of HF transceiver.				

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MDC-20 (Cont)	TAPE RECORDER switches					
	PLAY switch	Applies 28-vdc control power to appropriate PMP circuits and relays to select DSE outputs for transmission via USBE.	N/A	S-BAND-VOICE TAPE switch, (MDC-20)	None	The PMP power supply, when activated, supplies 28 vdc to the S-BAND-VOICE-TAPE switch (MDC). When the TAPE position is selected, this 28 vdc is supplied to the TAPE RECORDER-PLAY switch.
	PCM	Selects stored PCM data only.				PCM and NORM perform same function.
	NORM	Selects stored PCM and analog data. No real-time PCM data can be transmitted in this mode.				
	SPEED switch	Applies 28-vdc control power from TAPE RECORDER-FWD/REV switch (FWD or REV position) to DSE control logic.		TAPE RECORDER-FWD/REV switch, FWD or REV position	CT0012X	DSE control logic reverts to 15 ips (NORM) tape speed if power to FWD/REV switch is lost.
	HIGH	Selects high tape speed (120 IPS).				Used during DSE tape rewind and for playback of recorded LBR used for recording and playback of HBR.
	Norm (center)	Selects normal tape speed (15 IPS).				Used while recording LBR only. DSE cannot dump in LOW.
	LOW	Selects low tape speed (3.75 IPS).				
	RECORD/PLAY switch	Applies 28-vdc control power to DSE control logic.	T/C - GROUP 5 (MDC-22)	Flight and poststanding bus		DSE control logic requires the switch to be placed at other than OFF and FWD or REV selected prior to tape motion.
	RECORD	Activates DSE record electronics.				
	Off (center)	None				
	PLAY	Activates DSE playback electronics.				

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MDC-20 (Cont)	FWD/REV switch	Applies 28-vdc control power to: a. DSE control logic to activate tape transport in forward direction. b. TAPE RECORDER-SPEED switch.	T/C - GROUP 5 (MDC-22)	Flight and postlanding bus	None	DSE control logic requires this switch to be placed at other than OFF and RECORD or PLAY selected prior to tape motion.
	Off (center)	Removes 28 vdc from control logic and SPEED switches.				
	REV	Applies 28-vdc control power to: a. DSE control logic to activate tape transport in reverse direction b. TAPE RECORDER-SPEED switch.				
	PWR switches	Activates "latch" coil of relay in SCE, applying 3-phase a-c power from SIG COND S-BAND PA AC circuit breaker (MDC-22) to SCE power supply.  Activates "unlatch" coil of relay in SCE, removing 3-phase a-c power.				
	SCE switch					
	ON					
	OFF					This switch set to ON prior to launch and should remain on throughout entire mission.
	PMP switch					
	ON	Allows 3-phase a-c power from T/C - GROUP 2 AC circuit breaker to be applied to PMP 28 vdc power supply.				
	OFF	Activates relay in PMP to remove 3-phase a-c power from PMP 28 vdc power supply.				OFF position causes loss of normal voice, TV, ranging and S-band PCM TLM.

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MDC-20 (Cont)	TLM INPUTS switches		N/A	PCM/TLM Equipment and TAPE RECORD-RECORD/PLAY switch	None	Supplies 28-vdc control power from TAPE RECORDER-RECORD/PLAY switch (RECORD position) to the DSE control logic and ground for programmer control circuitry in the PCM/TLM equipment.
	PCM switch	a. Selects wide-band PCM TLM data mode (51.2 KBPS bit-rate) in PCM/TLM equipment. b. Selects normal-speed assurance mode of DSE.				The low (1.6 KBS) PCM bit-rate cannot also be commanded by the MSFN by an UDL real-time-command in this position.
	HIGH					UDL command from MSFN may change bit rate to high (51.2 kbs). Switch will, however, remain in LOW.
	LOW	a. Selects narrow-band PCM TLM data mode (1.6 KBPS bit-rate) in PCM/TLM equipment. b. Selects low-speed assurance mode in DSE.				
	BIOMED switch					
	1	Selects operational biomedical data from command pilot for transmission or storage in DSE.	BIOMED COMM - MN B (MDC-25) & T/C - GROUP 5 (MDC-22)	D-C main bus B & flight & postlanding bus (Refer to Remarks.)		Supplies 28-vdc power from BIOMED COMM-MN B circuit breaker to physiological amplifier of selected astronaut, and supplied 28 vdc from T/C - GROUP 5 circuit breaker to control transmission of proper PCM signal to indicate position of switch to MSFN.
	2	Selects operational biomedical data from senior pilot for transmission or storage in DSE.				
	3	Selects operational biomedical data from pilot for transmission or storage in DSE.				
	VHF ANTENNA switch	Applies 28-vdc control power to VHF antenna switch latching relay circuits. Connects VHF recovery antenna No. 2 to VHF multiplexer. Connects VHF portion of SCIN antenna on the -Z axis to VHF multiplexer.	T/C - GROUP 5 (MDC-22)	Flight and postlanding bus		This position not used until after parachute deployment and disreefing.
	RECOVERY					Upper and lower antennas manually selected to permit most advantageous reception and transmission of VHF-AM communications and VHF-FM telemetry.
	UPPER					

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MDC-20 (Cont)	LOWER	Connects VHF portion of SCIN antenna on the +Z axis to VHF multiplexer	T/C - GROUP 5 (MDC-22)	Flight and postlanding bus	None	Lower antenna will burn off on entry.
	He TANK indicators	Indicates SPS helium storage tank pressure when SPS TANK PRESS switch (MDC-20) is in the He position.	INSTRUMENTS—ESS MN A MN B (MDC-22)	D-C main buses A and B	SP0001P (He tank pressure)	Each indicator consists of d'Arsonval-type meter with fixed dial and movable pointer. Pointer movement is vertical as observed from crew couch.
	PRESS	Indicates SPS gaseous nitrogen storage tank pressure of engine pneumatic valve control system A and B when SPS TANK PRESS switch (MDC-20) is in the N <sub>2</sub> A or N <sub>2</sub> B position, respectively.			SP0600P (N <sub>2</sub> A tank pressure)	Pressure indicator display is in psia, and range is 0 to 5000 psia.
	N <sub>2</sub> TK PRESS				SP0601P (N <sub>2</sub> B tank pressure)	
	PRESSURE indicators					
	FUEL	Provides constant monitoring of SPS fuel tank regulated helium pressure.			SP0006P (fuel tank pressure)	Four indicators are identical in operation. Each consists of d'Arsonval-type meter with fixed dial and movable pointer. Pointer movement is vertical as observed from crew couch.
	OX	Provides constant monitoring of SPS oxidizer tank regulated helium pressure.			SP0003P (oxidizer tank pressure)	Each indicator is calibrated in psia with range of 0 to 300 psia.
	ENG INLET group					
	FUEL	Provides constant monitoring of SPS fuel pressure at the engine main propellant valves.			SP0010P (fuel line engine inlet)	
	OX	Provides constant monitoring of SPS oxidizer pressure at the engine main propellant valves.			SP0009P (oxidizer line engine inlet)	
	TEMPERATURE indicator	Propellant temperature is monitored in the engine fuel feed line plumbing at the gimbal ring of the engine. The indicator displays the measurement as noted in the Remarks column:			SP0048T (fuel line engine inlet)	Same indicator as helium tank press. Propellant temperature is indicated in degrees Fahrenheit. The range of the indicator is -100° to +200°F. When the indicator reads -40°F (equivalent propellant temperature of +40°F) the SPS HEATER switch is placed to position A or B. When the indicator reads +80°F (equivalent propellant temperature +120°F) the SPS HEATER switch is placed to OFF. The indicator has red line markings at +80°F and -40°F.

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MDC-20 (Cont)	SPS ENGINE INJECT VALVE indicators 1 (2, 3, 4)	Provides visual indication of SPS engine main propellant valves open or closed condition (one oxidizer and one fuel valve per pair and one indicator for each pair of valves).	T/C - GROUP 5 (MDC-22)	Flight and postlanding bus	Valve position: A-1 SP0022H A-2 SP0023H B-3 SP0024H B-4 SP0025H  <b>NOTE</b> Separate pickoffs for display and T/M signals.	Four identical indicators. Each is needle-movement-type meter with inputs supplied by position potentiometer located on valve actuator arm.  Left needle deflection indicates CLOSE; right deflection indicates OPEN.
	SPS TANK PRESS switch He  N <sub>2</sub> A  N <sub>2</sub> B	Connects SPS helium storage tank pressure output to He TANK PRESS indicator (MDC-20).  Connects SPS gaseous nitrogen storage tank pressure output of engine control valve system A to TK PRESS indicator (MDC-20).  Connects SPS gaseous nitrogen storage tank pressure output of engine control valve system B to TK PRESS indicator (MDC-20).	N/A	N/A	None	Three-position toggle switch used to select SPS helium or nitrogen tank pressure input to He TANK PRESS or N <sub>2</sub> TK PRESS indicator on MDC-20.
	SPS HELIUM switches (two, left hand and right hand)  AUTO  OFF	Two operationally identical switches.  Provides for automatic application and removal of power from helium isolation valve solenoid.	SPS-He VALVE MN A MN B (MDC-25)	D-C main buses A and B		Each switch is a three-way toggle switch. With this switch in the AUTO position, valve opening and closing is controlled automatically by G&N system and/or SCS. Complete manual control of valve position can be maintained by utilizing ON - OFF switch positions.  D-C main buses A and B provide power to helium pressurizing systems A and B, respectively.
		Removes power from helium isolation valve solenoid.				

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MDC-20 (Cont)	ON	Applies power to helium isolation valve solenoid.	SPS-He VALVE MN A MN B (MDC-25)	D-C main buses A and B	None	Each switch controls helium flow to one of two redundant pressure regulator assemblies.
	SPS HELIUM event indicators (two)	Striped-line display indicates open conditions of valve controlled by switch located directly below indicator. Gray display indicates closed condition.				Two identical indicators. Each is two-condition device with striped-line display controlled by solenoid action and gray display controlled by permanent magnet action.
	QUANTITY display windows OXID  FUEL	Digital counter display window indicating total oxidizer tank quantity remaining (in pounds times 20).  Digital counter display window indicating total fuel tank quantity remaining (in pounds times 10).	SPS-GAUGING MN A MN B AC 1 AC 2 (MDC-25)	400-cps a-c input from quantity gauging system control unit		Digital display in oxidizer quantity (OXID) window and fuel quantity (FUEL) window represent remaining tank quantities and are marked X20 and X10, respectively. These markings facilitate determination of correct remaining propellant quantities. Since desired oxidizer/fuel ratio is 2:1, digital display in both windows should be identical when propellant ratio is correct.
	UNBALANCE indicator	Indicates unbalance of remaining SPS propellants.				Indicator is graduated into six major divisions, each representing 100 pounds of propellant unbalance. Upper half indicates increased oxidizer flow required; lower half, decreased flow. Indicator needle at 0 (horizontal position) indicates desired propellant ratio.
	TEST/AUTO/TEST switch TEST (up)  AUTO  TEST (down)	Applies simulated input to propellant quantity gauging and utilization system control unit, causing digital display counters and UNBALANCE indicator to function for test check.  Normal operating position.  Applies simulated input for same purposes as TEST (up) position, except in reverse polarity.		D-C and a-c test inputs from quantity gauging system control unit		Three-position toggle switch, spring-loaded to AUTO position. TEST position allows for visual check of proper electrical and mechanical operation of propellant indicating devices. In addition to indicator checks, TEST position may be used to aid in isolating a malfunction in either primary or auxiliary propellant quantity sensing system.  Test rate for OXID digits is approximately 3 digits/second; FUEL 1.5 digits/second.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-20 (Cont)	OXID FLOW switch INCREASE	Supplies increased signal to propellant utilization valve PRI or SEC motor selected by VALVE switch. INCREASE position — 46.65 lb/sec.	SPS— GAUGING MN A MN B AC 1 AC 2 (MDC-25)	D-C and a-c test inputs from quantity gauging system control unit	None	Three-position toggle switch used as required to regulate oxidizer flow rate to maintain proper propellant utilization. Remaining propellant SPS unbalance may be determined by monitoring UNBALANCE meter or by calculations, utilizing information displayed in OXID and FUEL quantity digital display windows.  Maximum PU valve response time from increase to decrease position in 3.5 seconds.
	NORM	Supplies normal signal to propellant utilization valve PRI or SEC motor selected by VALVE switch. NORM position — 45.27 lb/sec at 70°F and 168±4 PSIG.				
	DECREASE	Supplies decreased signal to propellant utilization valve PRI or SEC motor selected by VALVE switch. DECREASE position — 43.87 lb/sec.				
	OXID FLOW event indicators Upper indicator  Lower indicator	Striped-line display indicates propellant utilization valve is in increased oxidizer flow rate position; gray display indicates it is not.  Striped-line display indicates propellant utilization valve is in decreased oxidizer flow rate position; gray display indicates it is not.				
	VALVE switch PRI  SEC	Applies power to propellant utilization valve primary servo amplifier.  Applies power to propellant utilization valve secondary servo amplifier.		D-C input from quantity gauging system		Two-position toggle switch which provides manual selection of primary or secondary gates in propellant utilization valve.  The PU valve secondary gate is capable of adjusting for increased, decreased, or normal oxidizer flow area regardless of a primary gate failure in any position.

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MDC-20 (Cont)	SENSOR switch  PRI  NORM  AUX	Applies output from primary propellant quantity sensing system to propellant quantity indicating and warning devices.  Applies outputs from both primary and auxiliary sensing systems to propellant quantity warning devices and output from primary propellant sensing system to propellant quantity indicating devices.  Applies output from auxiliary propellant sensing system to propellant quantity indicating and warning devices.	SPS- GAUGING MN A MN B AC 1 AC 2 (MDC-25)	400-cps a-c input from quantity gauging system control unit	None	Three-position toggle switch, with switch in NORM position during normal operation. This switch, when used in conjunction with TEST switch (MDC-20), can be useful in isolating a malfunction in propellant quantity sensing system.
MDC-21	SUIT COMPRESSOR selector switch  COMPR 1 AC 2  AC 1	Applies a-c power to motor of suit compressor No. 1 from bus No. 2.  Applies a-c power to motor of suit compressor No. 1 from bus No. 1.	ECS-SUIT COM-PRESSORS AC 2 ØA ØB ØC (MDC-22)  ECS-SUIT COM-PRESSORS AC 1 ØA ØB ØC (MDC-22)	A-C bus No. 2  A-C bus No. 1	None	Only one suit compressor is normally operated at a time, with second compressor for standby redundancy.  Output of each compressor is as follows: a. Prelaunch mode - 32.7 cfm and $\Delta P$ of 0.7 to 0.9 psi. b. Normal mode - 35 cfm and $\Delta P$ of 0.3 to 0.4 psi. c. Emergency mode - 33.6 cfm and $\Delta P$ of 0.2 to 0.3 psi.
	OFF  COMPR 2 AC 1	Removes a-c power from motors of suit compressors.  Applies a-c power to motor of suit compressor No. 2 from bus No. 1.				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-21 (Cont)	AC 1/1 AC 2/2	Applies a-c power to the following motors: a. NO. 1 suit compressor from bus NO. 1. b. NO. 2 suit compressor from bus NO. 2.	ECS-SUIT COM-PRESSORS AC 1 Ø A Ø B Ø C and AC 2 Ø A Ø B Ø C (MDC-22)	A-C buses No. 1 and 2	None	Switch position permits simultaneous operation of both suit compressors during periods of high suit heat loads.
	ECS GLYCOL pump selector switch PUMP 1 AC 2	Applies a-c power to motor of No. 1 water-glycol pump from bus No. 2	ECS-GLYCOL PUMPS- AC 2 Ø A Ø B Ø C (MDC-22)	A-C bus No. 2		Only one water-glycol pump can be operated at a time, with second pump for standby redundancy.
	AC 1	Applies a-c power to motor of No. 1 water-glycol pump from bus No. 1	ECS-GLYCOL PUMPS- AC 1 Ø A Ø B Ø C (MDC-22)	A-C bus No. 1		Pump design specification figures are 200 lb/hr flow at a pressure rise of 29.5 psi, with a pump inlet of 7.5±1.5 psig at 100°F (max). Actual flow varies inversely with system pressure drop.
	OFF PUMP 2 AC 1	Removes a-c power from motors of water-glycol pumps.  Applies a-c power to motor of No. 2 water-glycol pump from bus No. 1				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-21 (Cont)	AC 2	Applies a-c power to motor of No. 2 water-glycol pump from bus No. 2.	ECS-GLYCOL PUMPS-AC 2 Ø A Ø B Ø C (MDC-22)	A-C bus No. 2	None	
	CABIN AIR FAN switches 1 switch					
	ON	Applies a-c power to motor of No. 1 cabin air fan, directing airflow through cabin heat exchanger.	ECS-CABIN AIR FAN 1 Ø A Ø B Ø C (MDC-22)	A-C bus No. 1		Cabin air fans No. 1 and No. 2 are operated simultaneously to obtain adequate cooling.  Output of fan is as follows: a. Prelaunch mode - 171.45 cfm. b. Normal mode - 170.67 cfm. c. Emergency mode - 0 cfm (fan off).  In event of malfunction, fan No. 1 is turned off and fan closure cover manually installed over inlet to prevent backflow.
	OFF	Removes a-c power from motor of No. 1 cabin air fan.				
	2 switch					
	ON	Applies a-c power to motor of No. 2 cabin air fan, directing airflow through cabin heat exchanger.	ECS-CABIN AIR FAN 2 Ø A Ø B Ø C (MDC-22)	A-C bus No. 2		Cabin air fans No. 1 and No. 2 are operated simultaneously to obtain adequate cooling.  Output of fan is as follows: a. Prelaunch mode - 171.45 cfm. b. Normal mode - 170.67 cfm. c. Emergency mode - 0 cfm (fan off).  In event of malfunction, fan No. 2 is shut down and fan closure cover is manually installed over inlet to prevent backflow.
	OFF	Removes a-c power from motor of No. 2 cabin air fan.				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-21 (Cont)	POT H <sub>2</sub> O HEATER switch					
	MN A	Applies d-c power to potable water heater from main bus A.	ECS-POT H <sub>2</sub> O HTR MN A (MDC-22)	D-C main bus A	None	Two heating elements totaling 45 watts (20 and 25 watts each) are mounted at separate locations inside the food preparation water unit. Operating simultaneously, they heat the water from an inlet temperature of 60°F to 154±4°F. The maximum time to heat 1.9 lb of water (reservoir capacity) is approximately 2 hours.
	OFF	Removes d-c power from potable water heater.				
	MN B	Applies d-c power to potable water heater from main bus B.	ECS-POT H <sub>2</sub> O HTR MN B (MDC-22)	D-C main bus B		Under most normal conditions all space radiator valves are placed in the open position. Exceptions to this are during ground checkout and ascent. The only other time a valve is closed is when a radiator circuit is isolated in event of leakage.  Space radiator valves, which must be in the full open or full closed position, require 17 seconds (max) for full travel.
	ECS RADIATOR switches					
	Group I					
	A (on)	Applies a-c power to actuator of space radiator isolation valve 1A to place valve in open position, permitting water-glycol flow to the six-tube circuit of the radiator located in S/M sector V (-Y axis).	ECS-RAD VALVE AC 1 1A (MDC-22)	A-C bus No. 1 0A		
	OFF	Applies a-c power to actuator of space radiator isolation valve 1A to place valve in closed position, cutting off water-glycol flow to the radiator tube circuit.				
	B (on)	Applies a-c power to actuator of space radiator isolation valve 1B to place valve in open position, permitting water-glycol flow to the four-tube circuit of the radiator located in S/M sector V (-Y axis).	ECS-RAD VALVE AC 2 1B (MDC-22)	A-C bus No. 2 0A		
	OFF	Applies a-c power to actuator of space radiator isolation valve 1B to place valve in closed position, cutting off water-glycol flow to the radiator tube circuit.				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-21 (Cont)	Group 2				None	
	A (on)	Applies a-c power to actuator of space radiator isolation valve 2A to place valve in open position, permitting water-glycol flow to the six-tube circuit of the radiator located in S/M sector II (+Y axis).	ECS-RAD VALVE AC 2 2A (MDC-22)	A-C bus No. 2 ØC		
	OFF	Applies a-c power to actuator of space radiator isolation valve 2A to place valve in closed position, cutting off water-glycol flow to the radiator tube circuit.				
	B (on)	Applies a-c power to actuator of space radiator isolation valve 2B to place valve in open position, permitting water-glycol flow to the four-tube circuit of the radiator located in S/M sector II (+Y axis).	ECS-RAD VALVE AC 1 2B (MDC-22)	A-C bus No. 1 ØB		
	OFF	Applies a-c power to actuator of space radiator isolation valve 2B to place valve in closed position, cutting off water-glycol flow to the radiator tube circuit.				
	RCS HEATERS circuit breakers A MN B (20 amp)	Applies power from d-c main bus B to the following: a. SM RCS quad A package heater b. Normally open contacts of relay activated by CM RCS HTRS switch (RHFE-200) for CM RCS system B engine injector valve direct coils utilized for engine preheating.	N/A	+28 vdc		Thermal, push-pull manual reset-type circuit breakers with the amperage rating of each denoted by a white placard.

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MDC-21 (Cont)	B MN A (20 amp)	Applies power from d-c main bus A to the following: a. SM RCS quad B package heater b. Normally open contacts of relay activated by CM RCS HTRS switch (RHFE B-200) for CM RCS system A engine injector valve direct coils utilized for engine preheating.	N/A	+28 vdc	None	
	C MN B (5 amp)	Applies power from d-c main bus B to package heater in S/M RCS quad C.				
	D MN A (5 amp)	Applies power from d-c main bus A to package heater in S/M RCS quad D.				
	SNSR UNIT circuit breakers					
	DC BUS group					
	A (5 amp)	Applies d-c power from battery relay bus through MAIN BUS A-RESET switch to d-c main bus A undervoltage sensing unit.				Sensing unit is inoperative when MAIN BUS A-RESET switch is in the OFF position.
	B (5 amp)	Applies d-c power from battery relay bus through MAIN BUS B-RESET switch to d-c main bus B undervoltage sensing unit.				Sensing unit is inoperative when MAIN BUS B-RESET switch is in the OFF position.
	AC BUS group					
	1 (5 amp)	Applies d-c power from battery relay bus through AC BUS 1-RESET switch to a-c bus No. 1 over-undervoltage and overload sensing unit.				Sensing unit is inoperative when AC BUS 1-RESET switch is in the OFF position.
	2 (5 amp)	Applies d-c power from battery relay bus through AC BUS 2-RESET switch to a-c bus No. 2 over-undervoltage and overload sensing unit.				Sensing unit is inoperative when AC BUS 2-RESET switch is in the OFF position.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22	<b>FUEL CELL PUMP switches</b>					
	Switch 1	Is capable of selecting a-c bus No. 1, a-c bus No. 2, or off for fuel cell No. 1 pump motors.	FUEL CELL 1 - CIR & SEP MOTORS (MDC-22)	A-C bus No. 1	None	Two parallel pump motors are associated with each fuel cell. One motor drives the H <sub>2</sub> circulating pump and the water separation centrifuge. The other motor drives the glycol circulating pump. Switches are located between bus and c/b's.
	AC 1	Controls 3Ø a-c power from a-c bus No. 1 to fuel cell No. 1 pump motors.				
	OFF	Disconnects 3Ø a-c power from pump motors.				
	AC 2	Controls 3Ø a-c power from a-c bus No. 2 to fuel cell No. 1 pump motors.		A-C bus No. 2		
	Switch 2	Is capable of selecting a-c bus No. 1, a-c bus No. 2, or off for fuel cell No. 2 pump motors.	FUEL CELL 2 - CIR & SEP MOTORS (MDC-22)	A-C bus No. 1		
	AC 1	Controls 3Ø a-c power from a-c bus No. 1 to fuel cell No. 2 pump motors.				
	OFF	Disconnect 3Ø a-c power from pump motors.				
	AC 2	Controls 3Ø a-c power from a-c bus No. 2 to fuel cell No. 2 pump motors.		A-C bus No. 2		
	Switch 3	Is capable of selecting a-c bus No. 1, a-c bus No. 2, or off for fuel cell No. 3 pump motors.	FUEL CELL 3 - CIR & SEP MOTORS (MDC-22)	A-C bus No. 1		
	AC 1	Controls 3Ø a-c power from a-c bus No. 1 to fuel cell No. 3 pump motors.				
	OFF	Disconnects 3Ø a-c power from pump motors.				
	AC 2	Controls 3Ø a-c power from a-c bus No. 2 to fuel cell No. 3 pump motors.		A-C bus No. 2		

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	MAIN BUS TIE switches BAT A & C/AUTO/ OFF switch BAT A & C	Allows manual control of bus tie motor switch to: a. Connect battery bus A to d-c main bus A and battery C to d-c main bus B. b. Disconnect BATTERY CHARGER selector switch (MDC-18) from battery bus A and battery C.  In the event of an LES abort or normal CSM separation, this position allows the C/M RCS control box to control bus tie motor switch connecting battery bus A to d-c main bus A and battery C to d-c main bus B and disconnects BATTERY CHARGER selector switch (MDC-18).	BATTERY CHARGER-BAT A CHGE (MDC-22)	Battery bus A		Actuates motor-driven switch which accomplishes actual switching function.
	AUTO					
	OFF	Allows manual control of motor switch to: a. Disconnect battery bus A from d-c main bus A and battery C from d-c main bus B. b. Connects BATTERY CHARGER selector switch (MDC-18) to battery bus A and battery C.				
	BAT B & C/AUTO/ OFF switch BAT B & C	Allows manual control of bus tie motor switch to: a. Connect battery bus B to d-c main bus B and Battery C to d-c main bus A. b. Disconnects BATTERY CHARGER selector switch (MDC-18) from battery bus B and battery C.	BATTERY CHARGER-BAT B CHGE (MDC-22)	Battery bus B		Actuates motor-driven switch which accomplishes actual switching function.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	AUTO	In the event of an LES abort or normal CSM separation, this position allows the C/M RCS control box to control bus tie motor switch connecting battery bus B to d-c main bus B and battery C to d-c main bus A, and disconnects BATTERY CHARGER selector switch (MDC-18).	BATTERY CHARGER-BAT B CHGE (MDC-22)	Battery bus B	None	
	OFF	Allows manual control of motor switch to:  a. Disconnects battery bus B from d-c main bus B and battery C from d-c main bus A. b. Connect BATTERY CHARGER selector switch (MDC-18) to battery bus B and battery C.				
	BAT CHGR switch	Provides means of selecting a-c bus No. 1 or a-c bus No. 2 for battery charger a-c power source.	BATTERY CHARGER-AC PWR (MDC-22)	A-C bus No. 1		
	AC 1	Controls 3Ø a-c power from a-c bus No. 1 to battery charger during battery charging operation.		A-C bus No. 2		
	AC 2	Controls 3Ø a-c power from a-c bus No. 2 to battery charger during battery charging operation.				
	NON ESS BUS switch	Connects nonessential bus No. 1 and No. 2 to d-c main bus A.		D-C main bus A		Equipment associated with this switch is:  a. Scientific equipment bay No. 1 } NON ESS BUS NO. 2 b. Scientific equipment bay No. 2 } c. Scientific equipment hatch } d. Flight qualification recorder } NON ESS BUS NO. 1 e. Nonessential instrumentation } f. Voice recorder flag }
	MN A	Disconnects nonessential buses from d-c main buses		D-C main bus B		
	OFF	Connects nonessential bus No. 1 and No. 2 to d-c main bus B.				
	MN B					

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	G&N VIEWER switch	Provides means of selecting a-c bus No. 1 or a-c bus No. 2 for LEB panel brightness control, SCT and SXT reticle lights and signal conditioner.	VIEWER AC 1 and AC 2 (MDC-22)		None	
	AC 1	Selects 3Ø a-c power from a-c bus No. 1		A-C bus No. 1		
	AC 2	Selects 3Ø a-c power from a-c bus No. 2		A-C bus No. 2		
	TELCOM switches					
	ESS switch	Provides control of 3Ø a-c power to the TELECOMMUNICATIONS - GROUP - 2 and SIG CONDS-BAND PA (MDC-22) telecommunications (T/C) equipment which is essential to safety of flight.				Equipment associated with this switch is: a. Unified S-band equipment b. Premodulation processor c. Signal conditioning equipment d. S-band power amplifier.
	AC 1	Controls 3Ø a-c power from a-c bus No. 1 to essential T/C equipment controlled by TELECOMMUNICATIONS - GROUP - 2 and SIG COND S-BAND PA (MDC-22).	None	A-C bus No. 1		
	OFF	Disconnects 3Ø a-c power from essential T/C equipment.				
	AC 2	Controls 3Ø a-c power from a-c bus No. 2 to essential T/C equipment.		A-C bus No. 2		
	NONESS switch	Provides control of 3Ø a-c power to TELECOMMUNICATIONS - GROUP - 1 and PCM TLM (MDC-22) telecommunications (T/C) equipment which is not essential to safety of flight.				Equipment associated with this switch is: a. PCM telemetry b. VHF/FM transmitter c. C-band transponder d. Data storage equipment e. Flight qualification recorder f. Voice recorder
	AC 1	Controls 3Ø a-c power from a-c bus No. 1 to nonessential T/C equipment.				
	OFF	Disconnects 3Ø a-c power from nonessential T/C equipment.				
	AC 2	Controls 3Ø a-c power from a-c bus No. 2 to nonessential T/C equipment.		A-C bus No. 2		

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## CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	FUEL CELL 1 circuit breaker CIR & SEP MOTORS (3 amp)	a. Applies power from a-c bus No. 1 or 2 through FUEL CELL PUMP - 1 switch to C/B, and to circulator and separator pump motors in fuel cell 1. b. Provides 0A power to pH sensor probe.	N/A	115 vac 400 cps 30	None	
	H <sub>2</sub> & O <sub>2</sub> VALVE (10 amp)	Applies d-c power from battery relay bus to FUEL CELL 1 - REACTANTS switch (MDC-18), and to F/C VALVES-RESET switch (MDC-19).		+28 vdc		Opened after operation of F/C VALVES-RESET switch (MDC-19).
	BUS CONT (10 amp)	a. Applies d-c power from battery relay bus to F/C 1 bus disconnect control through FUEL CELL 1 - MAIN BUS A and MAIN BUS B switches (MDC-18). b. Provides power to reactants event indicator.				
	PURGE (5 amp)	Applies power from d-c main buses A and B to F/C 1 purge valve control through FUEL CELL 1 - O <sub>2</sub> PURGE - H <sub>2</sub> PURGE switch (MDC-18), and to H <sub>2</sub> PURGE LINE HTR switch (MDC-15).				H <sub>2</sub> PURGE LINE HTR switch (MDC-15) positioned to ON 30 minutes prior to an H <sub>2</sub> purge operation.
	FUEL CELL 2 circuit breakers CIR & SEP MOTORS (3 amp)	a. Applies power from a-c bus No. 1 or 2 through FUEL CELL PUMP - 2 switch to C/B, and to circulator and separator pump motors in fuel cell 2. b. Provides 0A power to pH sensor probe.		115 vac 400 cps 30		

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MDC-22 (Cont)	H <sub>2</sub> & O <sub>2</sub> VALVE (10 amp)	Applies d-c power from battery relay bus to FUEL CELL 2 - REACTANTS switch (MDC-18), and to F/C VALVES-RESET switch (MDC-19).	N/A	+28 vdc	None	Opened after operation of F/C VALVES-RESET switch (MDC-19).
	BUS CONT (10 amp)	a. Applies d-c power from battery relay bus to F/C 2 bus disconnect control through FUEL CELL 2 - MAIN BUS A and MAIN BUS B switches (MDC-18). b. Provides power to reactants & event indicator.				
	PURGE (5 amp)	Applies power from d-c main buses A and B to F/C 2 purge valve control through FUEL CELL 2 - O <sub>2</sub> PURGE - H <sub>2</sub> PURGE switch (MDC-18), and to H <sub>2</sub> PURGE LINE HTR switch (MDC-15).				
	FUEL CELL 3 circuitbreakers					
	CIR & SEP MOTORS (3 amp)	a. Applies power from a-c bus No. 1 or 2 through FUEL CELL PUMP - 3 switch to C/B, and to circulator and separator pump motors in fuel cell 3. b. Provides 0A power to pH sensor probe.				
	H <sub>2</sub> & O <sub>2</sub> VALVE (10 amp)	Applies d-c power from battery relay bus to FUEL CELL 3 - REACTANTS switch (MDC-18).		+28 vdc		Opened after operation of F/C VALVES-RESET switch (MDC-19).

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	BUS CONT (10 amp)	a. Applies d-c power from battery relay bus to F/C 3 bus disconnect control through FUEL CELL 3 - MAIN BUS A and MAIN BUS B switches (MDC-18) b. Provides power to reactants event indicator.	N/A	+28 vdc	None	
	PURGE (5 amp)	Applies power from d-c main buses A and B to F/C purge valve control through FUEL CELL 3 - O <sub>2</sub> PURGE - H <sub>2</sub> PURGE switch (MDC-18).				
	INVERTER CONTROL circuit breakers					
	1 (10 amp)	Applies d-c power from battery relay bus to AC INVERTER 1 and AC INVERTER 3 switches (MDC-18).				
	2 (10 amp)	Applies d-c power from battery relay bus to AC INVERTER 2 and AC INVERTER 1 switches (MDC-18).				
	3 (10 amp)	Applies d-c power from battery relay bus to AC INVERTER 2 and AC INVERTER 3 switches (MDC-18).				
	MASTER EVENT SEQ CONT circuit breakers					
	ARM group BAT A (5 amp)	Applies d-c power from battery bus A to the following switches: a. MESC-LOGIC ARM switches 1 and 2 (MDC-25) b. MASTER EVENT SEQ CONT - PYRO ARM switches 1 and 2 (MDC-24) c. LES MOTOR FIRE switch (MDC-5) d. CANARD DEPLOY switch (MDC-5)				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)		<p>e. ADAPT SEP switch (MDC-5) f. REACTION CONTROL SYSTEM - C/M PRESS switch (MDC-16) g. REACTION CONTROL SYSTEM - CMD/ON/OFF switch (MDC-16) h. C/M - S/M SEP switches 1 and 2 (MDC-15).</p>	N/A	+28 vdc	None	
	BAT B (5 amp)	<p>Applies d-c power from battery bus B to the following switches:</p> <p>a. MES-C-LOGIC ARM switches 1 and 2 (MDC-25) b. MASTER EVENT SEQ CONT - PYRO ARM switches 1 and 2 (MDC-24) c. LES MOTOR FIRE switch (MDC-5) d. CANARD DEPLOY switch (MDC-5) e. ADAPT SEP switch (MDC-5) f. REACTION CONTROL SYSTEM - C/M PRESS switch (MDC-16) g. REACTION CONTROL SYSTEM - CMD/ON/OFF switch (MDC-16) h. C/M - S/M SEP switches 1 and 2 (MDC-15).</p>				
	LOGIC group BAT A (15 amp)	<p>a. Applies d-c power from battery bus A to the logic A bus in the master event sequence controller when the MES-C - LOGIC ARM switches 1 and 2 (MDC-25) are in the LOGIC ARM position. The logic bus in turn provides power to the ABORT SYSTEM—MODE switches 1 and 2 and, during LES aborts, to the ABORT SYSTEM—OX DUMP switch.</p>				

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MDC-22 (Cont)	BAT B (15 amp)	b. Arms the abort switch in commanders translation control c. Provides part of the power to the LES and SPS abort circuitry.	N/A	+28 vdc	None	
		a. Applies d-c power from battery bus B to the logic B bus in the master event sequence controller when the MESC - LOGIC ARM switches 1 and 2 (MDC-25) are in the LOGIC ARM position. The logic bus in turn provides power to the ABORT SYSTEM—MODE switches 1 and 2 and, during LES aborts provides power to the ABORT SYSTEM—OX DUMP switch.				
		b. Arms the abort switch in commanders translation control. c. Provides part of the power for the LES and SPS abort circuitry.				
	DC SNR SIG circuit breakers MN A (5 amp) MN B (5 amp)	Applies power from d-c main bus A to d-c undervoltage sensing unit and DC INDICATORS switch.	None			Unit receives power from battery relay bus through circuit breakers on MDC-21.
		Applies power from d-c main bus B to d-c undervoltage sensing unit and DC INDICATORS switch.				
	CENTRAL TIMING SYS circuit breakers MN A (5 amp) MN B (5 amp)	Applies 28-vdc power to CTE power supply No. 1		D-C main bus A		The CTE contains two power supplies for redundancy, No. 1 and No. 2. If either one fails, the other will provide sufficient power for the CTE.
		Applies 28-vdc power to CTE power supply No. 2		D-C main bus B		
	SCIEN EQUIP circuit breakers SEB-1 (20 amp)	Applies power from non-essential bus to scientific equipment outlet in component A.		NON ESS BUS NO. 2 +28 vdc		Compartment A scientific equipment outlet is located in the LEB. (See figure 4-13.)

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MDC-22 (Cont)	SEB-2 (20 amp)	Applies power from non-essential bus to scientific equipment outlet in compartment B. (Proposed)	None	NON ESS BUS NO. 2 +28 vdc	None	(See figure 4-13.)
	BAT RLY BUS circuit breakers					
	BAT A (20 amp)	Applies d-c power from battery bus A through an isolation diode to battery relay bus.				
	BAT B (20 amp)	Applies d-c power from battery bus B through an isolation diode to battery relay bus.				
	BATTERY CHARGER circuit breakers					
	BAT A CHGE (10 amp)	Applies d-c power from battery bus A to MAIN BUS TIE - BAT A & C switch (MDC-22) and through contacts of bus tie motor switch to position A of BATTERY CHARGER selector switch (MDC-18).				
	BAT B CHGE (10 amp)	Applies d-c power from battery bus B to MAIN BUS TIE - BAT B & C switch (MDC-22) and through contacts of bus tie motor switch to position B of BATTERY CHARGER selector switch (MDC-18).		+28 vdc		
	MN A (5 amp)	Applies power from d-c main bus A, through an isolation diode, to BATTERY CHARGER selector switch (MDC-18) and d-c contacts of battery charger input-power control relay.				
	MN B (5 amp)	Applies power from d-c main bus B, through an isolation diode, to BATTERY CHARGER selector switch (MDC-18) and d-c contacts of battery charger input-power control relay.				

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MDC-22 (Cont)	AC PWR (2 amp)	Applies power from a-c bus No. 1 or a-c bus No. 2 to contacts of battery charger input-power control relay.	None	115 vac 400 cps 3 phase	None	
	TELECOMMUNICATIONS circuit breakers  GROUP number 1 AC (2 amp)	Applies 115-vac 3-phase power to: a. VHF-FM transmitter via internal power control relay controlled by VHF/FM switch (MDC-20) b. C-band transponder via power control relay K3 in circuit utilization box; relay is controlled by C-BAND switch (MDC-20) c. DSE; controlled by TAPE RECORDER switches (MDC-20) and logic circuitry in DSE d. FQR; controlled by FLIGHT QUAL RCDR switch (MDC-19) and logic circuitry in FQR. e. Voice recorder power converter, controlled by RCDR/HF-T/R and POWER-VOX switches MDC-13, -23, -26.		A-C bus No. 1 or 2		A-C bus supplying power to this equipment is determined by position of TELCOM—NON ESS switch (MDC-22).
	2 AC (2 amp)	Applies 115-vac 3-phase power to: a. USBE power supply via power control relay K2 in circuit utilization box, relay is controlled by S-BAND-XPONDER/OFF/XPONDER PWR AMPL switch (MDC-20) b. PMP power supply via internal power control relay, controlled by PWR-PMP switch and S-BAND-EMERG switch (MDC-20).				A-C bus supplying power to this equipment is determined by position of TELCOM—ESS switch (MDC-22).

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MDC-22 (Cont)	3 (5 amp)	Applies 28-vdc power to: a. Engineer's audio center b. POWER switch (MDC-23) c. RECOVERY—VHF-BCN switch (MDC-20) d. Commander's left microphone amplifier e. Engineer's right microphone amplifier.	None	Flight and Postlanding Bus	None	
	4 (10 amp)	Applies 28-vdc power to: a. Commander's audio center b. VHF/AM transmitter-receiver and HF transceiver keying relay coils c. RECOVERY—HF—ON/OFF switch (MDC-20) d. VHF-AM—T/R/OFF/REC switch (MDC-20) e. Navigator's left microphone amplifier f. Commander's right microphone amplifier.				
	5 (7.5 amp)	Applies 28-vdc power to: a. Navigator's audio center b. POWER switch (MDC-13) c. TAPE RECORDER—FWD/REV switch (MDC-20) d. TAPE RECORDER—RECORD/PLAY switch (MDC-20) e. POWER—SCE switch (MDC-20) f. POWER—PMP switch (MDC-20) g. S-BAND—EMERG switch (MDC-20) h. VHF-FM—ON/OFF switch (MDC-20)				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)		h. S-BAND—PWR AMPL switch (MDC-20) i. C-BAND—1 PULSE/2 PULSE switch (MDC-20) j. S-BAND PA equipment k. TV equipment l. DSE m. USBE power control relays n. UP-DATA switch (MDG-20) and up-data link equipment o. VHF ANTENNA switch (MDC-20) p. S-BAND ANTENNA switch through S-BAND-XPONDER/OFF/XPONDER PWR AMPL switch (MDC-20) q. Engineer's left microphone amplifier r. Navigator's right microphone amplifier s. BIO-MED PCM/TLM	None	Flight and Postlanding Bus	None	
	PCM TLM (2 amp)	Applies 115 vac 3-phase power to PCM/telemetry equipment.		AC NON ESS BUS 1 or 2		A-C bus supplying power to this equipment is determined by position of TELCOM—NON ESS switch (MDC-22).
	SIG COND S-BAND PA AC (2 amp)	Applies 115 vac 3-phase power to: a. SCE power supply via internal latching relay controlled by PWR-SCE switch (MDC-20) b. S-band PA power supplies via power control relay K1 in circuit utilization box; relay is controlled by S-BAND-XPONDER/OFF/XPONDER PWR AMPL switch (MDC-20).				A-C bus supplying power to this equipment is determined by position of TELCOM—ESS switch (MDC-22).
	SCIEN EQUIP HATCH circuit breaker (20 amp)	Applies power from nonessential bus to No. 2 to scientific equipment receptacle below RH and LH observation windows.		DC NON ESS BUS NO, 2 +28 vdc		(See figures 5-3 and 5-4.)

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MDC-22 (Cont)	ECS circuit breakers H <sub>2</sub> O ACCUM group MN A (5 amp)	Applies power from d-c main bus A to the following: a. H <sub>2</sub> O ACCUM-AUTO 1/MAN/AUTO 2 switch (MDC-13) b. H <sub>2</sub> O accumulator pump failure detection unit.	None	±28 vdc	None			
		Applies power from d-c main bus B to the following: a. H <sub>2</sub> O ACCUM-AUTO 1/MAN/AUTO 2 switch (MDC-13) b. H <sub>2</sub> O accumulator pump failure detection unit.						
		GAS ANAL circuit breaker AC 1 (2 amp)					Applies 0A a-c power to gas chromatograph package (GFE) located in scientific equipment compartment of LEB.	115 vac 400 cps 3ø
	INSTRUMENTS circuit breakers ESS group MN A (15 amp)	Applies 28-vdc power to ESSENTIAL - 1, -2, -3, & -4 circuit breakers on INST PWR CONT panel (RHEB-204).		D-C main bus A				
		Applies 28-vdc power to ESSENTIAL - 1, -2, -3, & -4 circuit breakers on INST PWR CONT panel (RHEB-204).		D-C main bus B				
		None						
		Applies 28-vdc power to NON ESSENTIAL-5 through -10 circuit breakers on INST PWR CONT panel (RHEB-204).		D-C main bus A or B				
		NON ESS BUS (5 amp)						
		NON ESS (15 amp)						

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MDC-22 (Cont)	RCDR NON ESS (5.0 amp)	Applies 28-vdc power to FQR. Applies 28-vdc power to VOICE RECORD event indicator (MDC-19)	None	D-C main bus A or B	None	The nonessential buses No. 1 and No. 2 obtain 28 vdc power from D-C main bus A or B, depending on posi- tion of NON ESS BUS switch (MDC-22).	
	SCIEN (7.5 amp)	Applies power from nonessential bus No. 1 for scientific instru- ments. (Not used.)					
	GUIDANCE & NAVIGATION circuit breakers						
		IMU HTR group					
		MN A (7.5 amp)	Applies power from d-c main bus A to IMU heaters.				
		MN B (7.5 amp)	Applies power from d-c main bus B to IMU heaters.				
	IMU group						
	MN A (25 amp)	Applies power from d-c main bus A to IMU.	N/A				
	MN B (25 amp)	Applies power from d-c main bus B to IMU.					
	COMPUTER group						
	MN A (10 amp)	Applies power from d-c main bus A to AGC.					
	MN B (10 amp)	Applies power from d-c main bus B to AGC.					
	OPTICS group						
	MN A (10 amp)	Applies power from d-c main bus A to optics.					
	MN B (10 amp)	Applies power from d-c main bus B to optics.					
	VIEWER group						
	AC 1 (1 amp)	Applies power from a-c bus No. 1 to G&N VIEWER switch.					
	AC 2 (1 amp)	Applies power from a-c bus No. 2 G&N VIEWER switch.			115 vac 400 cps 0B		

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	ENVIRONMENTAL CONTROL SYSTEM circuit breakers		N/A	115 vac 400 cps 3Ø		
	CABIN AIR FAN - 1 group	Applies 3Ø power from a-c bus No. 1 to the following: a. CABIN AIR FAN - 1 switch MDC-21) b. Waste management blower switch (RHEB-201).				
	AC 1 ØA (2 amp) ØB (2 amp) ØC (2 amp)					
	CABIN AIR FAN - 2 group	Applies power from a-c bus No. 2 to the following: a. 3Ø to CABIN AIR FAN-2 switch (MDC-21) b. ØC to CABIN TEMP - AUTO/MAN switch (MDC-13).				
	GLYCOL PUMPS group					
	AC 1	Applies power from a-c bus No. 1 to the following: a. 3Ø to ECS GLYCOL pump switch (MDC-21) b. ØA to GLYCOL EVAP - TEMP IN switch (MDC-13) c. ØB to SUIT EVAP switch (MDC-13) d. ØC to GLYCOL EVAP - STEAM PRESS - AUTO/MAN switch (MDC-13). e. ØC to GLYCOL EVAP - H <sub>2</sub> O FLOW switch (MDC-13).				
	ØA (2 amp) ØB (2 amp) ØC (2 amp)					
	AC 2	Applies 3Ø power from a-c bus No. 2 to ECS GLYCOL pump switch (MDC-21).				
	ØA (2 amp) ØB (2 amp) ØC (2 amp)					

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-22 (Cont)	TRANSDUCER group WASTE & POT H <sub>2</sub> O MN A (5 amp)	Applies power from d-c main bus A to the following pressure transducers: a. Waste water tank b. Potable water tank.	N/A	+28 vdc	None	
		Applies power from d-c main bus B to the following pressure transducer: a. Waste water tank b. Potable water tank.				
	PRESS GROUPS-1 MN A (5 amp)	Applies power from d-c main bus A to the following pressure transducers: a. Suit b. Compressor ΔP c. Water-glycol pump discharge d. Water-glycol accumulator (quantity) e. Water-gly evap steam.				
		Applies power from d-c main bus B to the following pressure transducers: a. Suit b. Compressor ΔP c. Water-glycol pump discharge d. Water-glycol accumulator (quantity) e. Water-gly evap steam.				
	PRESS GROUPS-2 MN A (5 amp)	Applies power from d-c main bus A to the following pressure transducers: a. O <sub>2</sub> flow rate b. O <sub>2</sub> supply regulator outlet (telemetered only)				

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MDC-22 (Cont)	MN B (5 amp)	c. Cabin d. CO <sub>2</sub> partial pressure.	N/A	+28 vdc	None	
		Applies power from d-c main bus B to the following pressure transducers: a. O <sub>2</sub> flow rate b. O <sub>2</sub> supply regulator outlet (telemetered only) c. Cabin d. CO <sub>2</sub> partial pressure.				
	TEMP group MN A (5 amp)	Applies power from d-c main bus A to the temperature transducer power supply, and in turn to the following transducer amplifiers: a. Water-gly evap liquid outlet b. Cabin c. Suit d. Steam duct (telemetered only) e. Space radiator outlet.				
		Applies power from d-c main bus B to the temperature transducer power supply, and in turn to the following transducer amplifiers: a. Water-gly evap liquid outlet b. Cabin c. Suit d. Steam duct (telemetered only) e. Space radiator outlet.				
	SUIT COMPRESSORS group AC 1 0A (2 amp) 0B (2 amp) 0C (2 amp)	Applies power from a-c bus No. 1 to SUIT COMPRESSOR switch (MDC-21).		115 vac 400 cps 30		

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MDC-22 (Cont)	AC 2 ØA (2 amp) ØB (2 amp) ØC (2 amp)	Applies power from a-c bus No. 2 to SUIT COMPRESSOR switch (MDC-21).	N/A	115 vac 400 cps 3Ø	None	
	RAD VALVE group					
	AC 1 1A (2 amp)	Applies ØA power from a-c bus No. 1 to ECS - RADIATOR-1-A switch (MDC-21).				
	2B (2 amp)	Applies ØB power from a-c bus No. 1 to ECS - RADIATOR-2-B switch (MDC-21).				
	AC 2 1B (2 amp)	Applies ØA power from a-c bus No. 2 to ECS - RADIATOR-1-B switch (MDC-21).				
	2A (2 amp)	Applies ØC power from a-c bus No. 2 to ECS - RADIATOR-2-A switch (MDC-21).				
	POT H <sub>2</sub> O HTR group MN A (5 amp)	Applies power from d-c main bus A to the following: a. POT H <sub>2</sub> O HEATER switch (MDC-21) b. GLYCOL EVAP - H <sub>2</sub> O FLOW switch (MDC-13).		+28 vdc		
	MN B (5 amp)	Applies power from d-c main bus B to the following: a. POT H <sub>2</sub> O HEATER switch (MDC-21) b. GLYCOL EVAP - H <sub>2</sub> O FLOW switch (MDC-13) c. WASTE H <sub>2</sub> O TK REFILL switch (MDC-13).				

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MDC-22 (Cont)	CRYOGENIC TANK FAN MOTORS circuit breakers  AC 1 group	Applies a-c $\emptyset$ A power from a-c bus No. 1 $\emptyset$ A to: a. H <sub>2</sub> FANS - 1 switch (MDC-13) b. O <sub>2</sub> FANS - 1 switch (MDC-13).	N/A	115 vac $\emptyset$ A	None	
		Applies a-c $\emptyset$ B power from a-c bus No. 1 $\emptyset$ B to: a. H <sub>2</sub> FANS - 1 switch (MDC-13) b. O <sub>2</sub> FANS - 1 switch (MDC-13).		115 vac $\emptyset$ B		
		Applies a-c $\emptyset$ C power from a-c bus No. 1 $\emptyset$ C to: a. H <sub>2</sub> FANS - 1 switch (MDC-13) b. O <sub>2</sub> FANS - 1 switch (MDC-13).		115 vac $\emptyset$ C		
		Applies a-c $\emptyset$ A power from a-c bus No. 2 $\emptyset$ A to: a. H <sub>2</sub> FANS - 2 switch (MDC-13) b. O <sub>2</sub> FANS - 2 switch (MDC-13).		115 vac $\emptyset$ A		
	AC 2 group	Applies a-c $\emptyset$ B power from a-c bus No. 2 $\emptyset$ B to: a. H <sub>2</sub> FANS - 2 switch (MDC-13) b. O <sub>2</sub> FANS - 2 switch (MDC-13).		115 vac $\emptyset$ B		
		Applies a-c $\emptyset$ C power from a-c bus No. 2 $\emptyset$ C to: a. H <sub>2</sub> FANS - 2 switch (MDC-13) b. O <sub>2</sub> FANS - 2 switch (MDC-13).		115 vac $\emptyset$ C		

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MDC-22 (Cont)	CRYOGENIC SYSTEM circuit breakers		N/A	+28 vdc	None	
	TANK HEATERS group					
	H <sub>2</sub> circuit breakers	Applies power from d-c main bus A to H <sub>2</sub> HEATERS switch (MDC-13).				
	MN A (5 amp)					
	MN B (5 amp)	Applies power from d-c main bus B to H <sub>2</sub> HEATERS switch (MDC-13).				
	O <sub>2</sub> circuit breakers					
MDC-23	MN A (15 amp)	Applies power from d-c main bus A to O <sub>2</sub> HEATERS switch (MDC-13).	COUGH ATTEN MN A MN B FLOOD- LIGHTS (MDC-25)	115 vac 400 cps ØC	None	FLOODLIGHTS controls on MDC-23, -26, and LEB-100 are functionally identical and each controls the floodlights in its respective area.
	MN B (15 amp)	Applies power from d-c main bus B to O <sub>2</sub> HEATERS switch (MDC-13).				
	QTY AMPL group					
	AC1-ØC (2 amp)	Applies power from a-c bus No. 1 (ØC) to H <sub>2</sub> and O <sub>2</sub> No. 1 tanks signal conditioning boxes.				
	AC2-ØC (2 amp)	Applies power from a-c bus No. 2 (ØC) to H <sub>2</sub> and O <sub>2</sub> No. 2 tanks signal conditioning boxes.				
	PRIMARY rheostat					
MDC-23	OFF	Removes power from C/M primary floodlights.	D-C main buses A and B			The rheostat control may be adjusted for desired brightness of primary
	BRIGHT	Indicates maximum floodlight brightness has been reached.				
	SECONDARY switch					
MDC-23	ON	Illuminates secondary floodlights.				
	OFF	Removes power from secondary floodlights.				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-23 (Cont)	C/W LAMP TEST switch		CAUT/ WARN- MN A MN B (MDC-25)	D-C main buses A and B	None	Lamp check of G&N condition lights and the MASTER ALARM light on LEB-103 is accomplished by pressing CHECK CONDITION LAMPS switch (LEB-105).  Master alarm tone is not activated by test illumination of lights.
	1	Completes d-c ground return path for test illumination of system status lights on MDC-10 and the MASTER ALARM switch-lights on MDC-3 and -18.				
	OFF	Opens d-c ground return path of lamp test circuit, extinguishing system status lights on MDC-10 and -11.				
	2	Completes d-c ground return path for test illumination of system status lights on MDC-11.				
	POWER switch	Controls power to pilots module in audio center equipment.	T/C— GROUP 3 (MDC-22)	Flight and postlanding bus		The audio center will not be activated unless the POWER switch is in PTT or VOX position.
	PTT	Applies d-c power to audio and control circuits.				Intercom capability when cobra cable PTT/CW switch is in CW and transmit when switch is in PTT.
	OFF	Removes power from pilots audio center equipment module and controls.				
	VOX	a. Applies d-c power to audio and control circuits b. Enables VOX control of mike amplifier by supplying ground to VOX circuitry.				VOX operation permits voice transmission and transmitter keying of intercom. HF recovery transceiver and voice recorder when cobra cable PTT/CW switch is at PTT.
	S-BAND switch		N/A	Audio center equipment		The S-BAND, HF, VHF-AM, and INTERCOM switches all control ground return paths for appropriate diode switching and isolation circuitry in the pilots module of the audio center equipment to allow transmission and reception, or reception alone, of voice signals over selected equipment. The HF and VHF-AM switches also provide ground return paths for the HF and VHF-AM transmitter keying circuits when in the T/R position.
	T/R	No effect. S-band T/R function supplied by cobra cable PTT key.				
	OFF	Prevents pilot from transmitting or receiving voice over USBE.				
	RCV	Enables pilot to receive voice from USBE.				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-23 (Cont)	RCDR/HF switch		N/A	Audio center equipment	None	Provides power ground through audio center VOX circuit for HF transceiver transmit-receive relay and voice recorder power relay.
	T/R	a. Enables pilot to transmit and receive voice over HF transceiver when operating in AM or SSB mode. b. Enables voice recorder through VOX circuit.				
	OFF	Prevents pilot from transmitting or receiving voice over HF transceiver.				
	RCV	Enables pilot to receive voice from HF transceiver when operating in AM or SSB mode.				VHF-AM transmits, in addition to S-band voice, when cobra cable PTT key is closed. Cobra cable PTT/CW switches must be at PTT, and audio center POWER switch must be at PTT.
	VHF AM switch					
	T/R	Enables pilot to transmit and receive voice over VHF/AM transmitter-receiver when operating in T/R mode.				
	OFF	Prevents pilot from transmitting or receiving voice over VHF-AM transmitter-receiver.				
	RCV	Enables pilot to receive voice from VHF-AM transmitter-receiver.				Audio center POWER switch must be at VOX to enable mike amplifier when cobra cable PTT/CW switch is at PTT.
	INTERCOM switch					
	T/R	Enables pilot to transmit and receive voice over the intercom system.				
	OFF	Prevents pilot from transmitting or receiving voice over intercom system.				
	RCV	Enables pilot to receive voice from intercom system.				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-23 (Cont)	VOX SENS control	Increase or decreases sensitivity of voice-operated relay circuitry in pilots audio center module.	N/A	Audio center equipment	None	These three controls are thumbwheel-type potentiometers which may be rotated upward or downward, as required.
	INTERCOM BALANCE control	Increases or decreases level of audio signal received by pilot from RF equipment relative to that received from intercom bus.				Position 9 most sensitive
	VOLUME control	Increases or decreases level of audio signal from pilot's ear-phone amplifier to earphone.				
MDC-24	EDS POWER switch ON OFF	Supplies entry battery A, B, and C power to the EDS buses 1, 2, and 3. Removes power from EDS buses 1, 2, and 3.	EDS-1, 2, 3 BAT A BAT C and BAT B (MDC-25)	Battery buses A, B, and entry battery C	None	Closing of the EDS POWER switch provides power to the EDS display circuitry and also supplies power for the EDS auto abort initiating circuitry.
	MASTER EVENT SEQ CONT - PYRO ARM switches Switches 1 and 2 PYRO ARM	Energizes relays in the MESC which perform the following: a. Connects pyro battery A to the MESC pyro bus A b. Connects pyro battery B to the MESC pyro bus B c. Connects pyro battery A to the C/M RCSC pyro bus A d. Connects pyro battery B to the C/M RCSC pyro bus B. Removes pyro battery power from the MESC pyro buses A and B, and RCS controllers.	MASTER EVENT SEQ CONT - A ARM B BAT A and BAT B (MDC-22)	Battery buses A and B	CD0005V DC voltage pyro bus A  CD0006V DC voltage pyro bus B	Lever lock-type switches are locked in the SAFE position and must be unlocked before they can be set to PYRO ARM position.  The lock and guard assembly must be unlocked with a key prior to hatch closeout.  The range safety officer will have possession of the key.
	SAFE					
	SCS GROUP 2 controls TVC 2 POWER switch AC 1	Applies a-c power to the gimbal positioning portion of the following: a. Yaw ECA b. Pitch ECA c. Redundant gimbal trim pot.	SCS - GROUP 2 AC 1 (MDC-25)	A-C bus No. 1		TVC 2 POWER switch supplies power to the redundant TVC electronics. Switch must be set to AC 1 or AC 2 position during any ΔV maneuver. It will provide the backup TVC capability required for automatic switchover from TVC 1 in the event of a malfunction. MTVC can only be accomplished using TVC 2 electronics. The TVC 2 power switch also provides power to the MTVC electronics.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-24 (Cont)	OFF	Removes a-c power from units supplied by AC 1 and AC 2 positions.	SCS— GROUP 2 AC 1 (MDC-25)	A-C bus No. 1	None	
	AC 2	Applies a-c power to the following: a. Yaw ECA b. Pitch ECA c. Redundant gimbal trim pot.	SCS— GROUP 2 AC 2 (MDC-25)	A-C bus No. 2		
	ROTATION CONTROL POWER switch					
	AC 1	Applies a-c power to the following: a. Command pilot's rotation control b. Senior pilot's rotation control c. Pitch ECA d. Yaw ECA e. Roll ECA	SCS— GROUP 2 AC 1 (MDC-25)	A-C bus No. 1 øA		
	OFF	Removes a-c power from units supplied by positions 1 and 2.				
	AC 2	Applies a-c power to the following: a. Command pilot's rotation control b. Senior pilot's rotation control c. Pitch ECA d. Yaw ECA e. Roll ECA	SCS— GROUP 2 AC 2 (MDC-25)	A-C bus No. 2 øA		Switch is a three-position toggle and must be in either the 1 or 2 position for normal rotation control operation.  This switch has no effect on the rotation control direct mode function.  Power for the two rotation controls is provided through the yaw, pitch, and roll ECAs. The power applied to yaw, pitch, and roll ECAs is demodulator reference voltage for rotation control output signals.
	BMAG POWER switch					
	AC 1	Applies a-c and d-c power to the following: a. DISPLAY/AGAA ECA b. Pitch ECA c. Yaw ECA d. Roll ECA e. Attitude gyros spin motor power through DISPLAY/AGAA ECA	SCS— GROUP 2 AC 1 MN A (MDC-25)	A-C bus No. 1 D-C main bus A		The power applied to DISPLAY/AGAA ECS is used to operate the BMAGs, torquing amplifiers, and preamplifiers in the AGAA. The power applied to pitch, yaw, and roll ECAs is demodulator reference voltage for BMAG error signal.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identify	Remarks
MDC-24 (Cont)	OFF	Removes a-c and d-c power from units supplied by position AC 1 and AC 2.	SCS— GROUP 2 AC 1 MN A (MDC-25)	A-C bus No. 1 D-C main bus A	None	Provides power for backup rate function.
	AC 2	Applies a-c and d-c power to the following: a. DISPLAY/AGAA ECS b. Pitch ECA c. Yaw ECA d. Roll ECA e. Attitude gyros spin motor power through DISPLAY/AGAA ECA.	SCS— GROUP 2 AC 2 MN B (MDC-25)	A-C bus No. 2 D-C main bus B		
	SCS GROUP 1 controls PARTIAL SCS POWER switch AC 1	Applies a-c and d-c power to the following: a. DISPLAY/AGAA ECA b. Pitch ECA c. Roll ECA d. Auxiliary ECA e. Yaw ECA f. Velocity change indicator g. Attitude set/gimbal position indicator.	SCS— GROUP 1 AC 1 MN A (MDC-25)	A-C bus No. 1 D-C main bus A		Switches are three-position rotary type. Refer to section 6, Normal/Backup Procedures, for the various switch positions required for the flight control modes. D-C voltage is provided to AS/GPI and the FDAI ALIGN switch. Three-phase a-c voltage is provided for the following: a. Aux ECA demodulator reference voltages and AGCU power supplies b. FDAI total attitude display motor, and associated electronics. Phase A a-c voltage is provided for the following: a. FDAI error needles b. FDAI ball drive servo amplifier c. FDAI rate needles for backup rate d. FDAI self-test circuit e. AS/GPI gimbal position excitation voltage f. Square wave generator reference voltage g. AGCU amplifier demodulator reference voltage.
	OFF  AC 2	Removes a-c and d-c power from units supplied by AC 1 and AC 2 positions.  Applies a-c and d-c power to the following: a. DISPLAY/AGAA ECA b. Pitch ECA c. Roll ECA d. Auxiliary ECA e. Yaw ECA f. Velocity change indicator g. Attitude set/gimbal position indicator.	SCS— GROUP 1 AC 2 MN B (MDC-25)	A-C bus No. 2 D-C main bus B		

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-24 (Cont)	RATE GYRO POWER switch AC 1	Applies a-c power to the following: a. Rate gyro assembly. b. Yaw ECA c. Pitch ECA d. Roll ECA e. Display/AGAA ECA: Removes a-c power from units supplied by AC 1 and AC 2 positions.	SCS— GROUP 1 AC 1 (MDC-25)	A-C bus No. 1	None	The RATE GYRO POWER switch applies three-phase, 115-vac power to the rate gyro assembly.  Phase A, 115-vac power is provided for the following: a. Roll, pitch, yaw ECA rate demodulator reference voltage. b. Roll, pitch, and yaw rate demodulators reference in display/AGAA ECA.
	OFF	Applies a-c power to the following: a. Rate gyro assembly b. Yaw ECA c. Pitch ECA d. Roll ECA e. Display/AGAA ECA.	SCS— GROUP 1 AC 2 (MDC-25)	A-C bus No. 2		
	AC 2					
	TVC 1 POWER switch AC 1  OFF  AC 2	a. Applies a-c power to the pitch and yaw ECAs. b. Applies d-c power to the DISPLAY/AGAA ECA c. X-axis accelerometer.  Removes a-c and d-c power from units supplied by AC 1 and AC 2 positions.  a. Applies a-c power to the pitch and yaw ECAs. b. Applies d-c power to the DISPLAY/AGAA ECA. c. X-axis accelerometer.	SCS— GROUP 1 AC 1 MN A (MDC-25)  SCS— GROUP 1 AC 2 MN B (MDC-25)	A-C bus No. 1 D-C main bus A  A-C bus No. 2 D-C main bus B		The TVC 1 POWER switch applies 115 vac and 28 vdc to the pitch and yaw TVC power supplies in the TVC electronics.  Provide necessary power for operating the $\Delta V$ REMAINING electronics. After completion of a burn, the switch must be placed to OFF then on to reactivate the $\Delta V$ inhibit circuit.  Provides power to the X-axis accelerometer on associated electronics through circuits in the display/AGAA ECA.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-24 (Cont)	DIRECT O <sub>2</sub> metering valve	Permits controlled flow of oxygen directly into suit circuit.	N/A	N/A	None	Valve has a shaft rotation of 1-3/4 turns from OPEN to close, and is manually controlled by a T-handle tool. This tool is stowed in DIRECT O <sub>2</sub> valve socket for use in positioning other valves accessible to crewman in LH couch. A second T-handle tool is stowed in LHEB-314 for operating valves in that area.
	OPEN (ccw)					Valve is opened in event of contamination or inability of demand pressure regulator to maintain minimum pressure. It may also be opened for cooling during descent, if necessary. In full open position flow rate is 0.66 pound/minute for approximately 5 minutes.
	Close (cw)	Shuts off flow of oxygen directly into suit circuit.				Normal position of valve is closed.
MDC-25	POSTLANDING controls  FLOAT BAG 1 PL BUS circuit breaker (5 amp)  VENT FAN group  PL BUS-FLOAT BAG 2 circuit breaker (5 amp)  HIGH/LOW/OFF switch  HIGH	Applies d-c power from the flight and postlanding bus to the POST-LANDING-FLOAT BAG switch No. 1 (MDC-25).  Applies d-c power from flight and postlanding bus to the following: a. FLOAT BAG switch 2 (MDC-25) b. VENT FAN-HIGH/LOW/OFF switch (MDC-25).  Applies d-c power to the following: a. Inlet and outlet vent valve motors, placing valves in open position. b. Vent fan motor for high flow output.	N/A	+28 vdc	None	
			POST-LANDING-VENT FAN-PL BUS-FLOAT BAG 2 (MDC-25)	Flight and postlanding bus		Prior to switch actuation, lockpins installed in both vent valves must be pulled.  Output of cabin vent fan in HIGH is 150 cfm. Cabin vent valve full travel requires 1.5 seconds (max).

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MDC-25 (Cont)	LOW	Applies d-c power to the following: a. Inlet and outlet vent valve motors, placing valve in open position. b. Vent fan motor for low flow output.	POST-LANDING— VENT FAN— PL BUS— FLOAT BAG 2 (MDC-25)	Flight and postlanding bus	None	Output of cabin vent fan in LOW is 100 cfm. Cabin vent valve full travel requires 1.5 seconds (max).
	OFF	Removes d-c power from motor of cabin vent fan, and applies power to motors of inlet and outlet cabin vent valves, placing valves in closed position.				Both vent valves will be immediately closed by activation of the PLV attitude switch when the C/M becomes inverted or rolls beyond a specified limit. Switch must be set to OFF position before reactivating the PLV.
	FLOAT BAG group Switch 1					
	FILL	Starts two compressors which inflate flotation bag No. 1	POST-LANDING— FLOAT BAG 1 PL BUS (MDC-25)			Lever lock-type switch. Flotation bag No. 1 is located on the +Y axis in the forward compartment of the C/M.
	Center	Neutral (off) position.				Solenoid valve in "seal" mode.
	VENT	Disconnects 28 vdc from the two compressors and opens vent line to flotation bag No. 1				The switch must remain in the VENT position during launch and throughout flight.
	Switch 2					Lever lock-type switch.
	FILL	Starts two compressors which inflate flotation bag No. 2.	POST-LANDING— VENT FAN-PL BUS— FLOAT BAG 2 (MDC-25)			Flotation bag No. 2 is located on the +Z axis in the forward compartment of the C/M.
	Center	Neutral (off) position.				Solenoid valve in "seal" mode.
	VENT	Disconnects 28 vdc from the two compressors and opens vent line to flotation bag No. 2.				The switch must remain in the VENT position during launch and throughout flight.
	Switch 3			Battery bus A		Lever lock-type switch
	FILL	Starts two compressors which inflate flotation bag No. 3.	ELS-A BAT A— FLOAT BAG 3 (MDC-25)			Flotation bag No. 3 is located on the +Z axis in the forward compartment of the C/M.
	Center	Neutral (off) position				Solenoid valve in "seal" mode.
	VENT	Disconnects 28 vdc from the two compressors and opens vent line to flotation bag No. 3				The switch must remain in the VENT position during launch and throughout flight.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-25 (Cont)	ANTENNA DEPLOY switches	Connects 28 vdc to the postlanding antenna deploy circuitry.	PYRO A GROUP—SEQ A and PYRO B group - SEQ B (LEB-150)	Pyro bus A and pyro bus B in the MESC when the MASTER EVENT SEQ CONT—PYRO switches A and B are in the ARM position	None	Two-position toggle switch that is set to A after landing when C/M is in upright position.
	DEPLOY	Normal position, no function.				
	A	Connects 28 vdc to the postlanding antenna deploy circuitry. Backup switch for DEPLOY switch A.	MASTER EVENT SEQ CONT - A ARM B BAT A and BAT B (MDC-22)	Battery buses A and B	CD0200V D-C voltage logic bus A CD0201V D-C voltage logic bus B	Two-position toggle switch that is set to B after landing when C/M is in upright position.
	OFF	Normal position, no function.				
	B	Connects 28 vdc to the postlanding antenna deploy circuitry. Backup switch for DEPLOY switch A.				
	OFF	Normal position, no function.				
	MESC—LOGIC ARM switches	Energizes relays in both MESC which perform the following: a. Connects battery bus A to the MESC A logic bus A b. Connects battery bus B to the MESC B logic bus B.				Lever lock-type switches.
	Switches 1 and 2					
	LOGIC ARM					
	OFF	Removes 28 vdc from MESC logic buses A and B.				
	EVENT TIMER circuit breakers	Applies d-c power from d-c main bus A to event timer switches (MDC-8).	N/A	+28 vdc	None	
	MN A (5 amp)	Applies d-c power from d-c main bus B to event timer switches (MDC-8).				
	MN B (5 amp)	Applies d-c power from d-c main bus B to event timer switches (MDC-8).				
	COUCH ATTEN - FLOOD-LIGHTS circuit breakers	Applies d-c power from d-c main bus A to the following controls: a. FLOODLIGHTS-PRIMARY rheostat (MDC-26).				
	MN A (15 amp)					

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-25 (Cont)	MN B (15 amp)	b. LIGHTING-FLOODS-PRIMARY rheostat (LEB-100) c. FLOODLIGHTS-SECONDARY switch (MDC-23) d. COUCH UNLOCK switch (MDC-8) e. LIGHTING-FLOODS-CLOCKS switch (LEB-100)	N/A	+28 vdc	None	
		Applies d-c power from d-c main bus B to the following controls: a. FLOODLIGHTS-PRIMARY rheostat (MDC-23) b. LIGHTING-FLOODS-SEC switch (LEB-100) c. FLOODLIGHTS-SECONDARY switch (MDC-26) d. COUCH UNLOCK switch (MDC-8).				
	STABILIZATION & CONTROL SYSTEM circuit breakers (top row)  DIRECT CONT group  MN A (30 amp)	Applies power from d-c main bus A to the following: a. DIRECT RCS switch on MDC-8 b. DIRECT ULLAGE switch on MDC-7 c. NORMAL/OFF/DIRECT ON switch on MDC-7 d. Arms command pilot's rotation control for direct commands through direct RCS switch				
	MN B (30 amp)	Applies power from d-c main bus B to the following: a. DIRECT RCS switch on MDC-8 b. DIRECT ULLAGE switch on MDC-7				

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MDC-25 (Cont)	A & C ROLL group MN A (20 amp)	c. NORMAL/OFF/DIRECT ON switch on MDC-7	N/A	+28 vdc	None	
		d. Arms senior pilot's rotation control for direct commands, through direct RCS switch.				
		Applies power from d-c main bus A to A & C ROLL channel switch on MDC-8.				Maneuver function - engine activation
		Applies power from d-c main bus B to A & C ROLL channel switch on MDC-8.				
	B & D ROLL group MN A (20 amp)	Applies power from d-c main bus A to B & D ROLL channel switch on MDC-8.				
		Applies power from d-c main bus B to B & D ROLL channel switch on MDC-8.				
	PITCH group MN A (20 amp)	Applies power from d-c main bus A to PITCH channel switch on MDC-8.				
		Applies power from d-c main bus B to PITCH channel switch on MDC-8.				
	YAW group MN A (20 amp)	Applies power from d-c main bus A to YAW channel switch on MDC-8.				
		Applies power from d-c main bus B to YAW channel switch on MDC-8.				
	MN B (20 amp)					
	MN B (20 amp)					

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MDC-25 (Cont)	STABILIZATION & CONTROL SYSTEM controls (bottom row)					
	FDAI LTG switch	Controls application of a-c power to the FDAI brightness control on MDC-2 for FDAI lighting and for illumination of the lamp in the THRUST ON switch on MDC-7.	SCS — GROUP 2 AC 1 or AC 2	A-C bus 1 or a-c bus 2		
	AC 1	Applies a-c bus 1 phase B power to FDAI brightness control.				
	OFF	Removes all a-c power from FDAI brightness control.				
	AC 2	Applies a-c bus 2 phase B power to FDAI brightness control.				
	GROUP 1 circuit breakers		N/A	115 vac 400 cps 3 phase		
	AC 1 (2 amp)	Applies power from a-c bus No. 1 to the following switches on MDC-24: a. SCS POWER b. RATE GYRO POWER c. TVC 1 POWER.				
	AC 2 (2 amp)	Applies power from a-c bus No. 2 to the following switches on MDC-24: a. SCS POWER b. RATE GYRO POWER c. TVC 1 POWER.				
	GROUP 2 circuit breakers					
	AC 1 (2 amp)	Applies power from a-c bus No. 1 to the following switches on MDC-24: a. BMAG POWER b. ROTATION CONTROL POWER c. TVC 2 POWER				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-25 (Cont)	AC 2 (2 amp)	Applies power from a-c bus No. 2 to the following switches on MDC-24: a. BMAG POWER b. ROTATION CONTROL POWER c. TVC 2 POWER.	N/A	115 vac 400 cps 3 phase	None	
	GROUP 1 circuit breakers MN A (15 amp)	Applies power from d-c main bus A to the following: a. SCS POWER switch on MDC-24 b. TVC 1 POWER switch on MDC-24 c. SCS switches on MDC-8 d. Translation control prior to CM-SM separation.		+28 vdc		
	MN B (15 amp)	Applies power from d-c main bus B to the following: a. SCS POWER switch on MDC-24 b. TVC 1 POWER switch on MDC-24 c. SCS switches on MDC-8 d. Translation control prior to CM-SM separation.				
	GROUP 2 circuit breakers MN A (15 amp)	Applies power from d-c main bus A to the following: a. BMAG POWER switch on MDC-24 b. Command pilot's rotation control c. Command pilot's translation control.				

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MDC-25 (Cont)	MN B (15 amp)	Applies power from d-c main bus B to the following: a. TVC 2 POWER switch on MDC-24 b. Senior pilot's rotation control c. Senior pilot's translation control.	N/A	+28 vdc	None	
	BIO MED COMM circuit breakers					
	MN A (5 amp)	Used on unmanned mission only.				
	MN B (5 amp)	Applies power from d-c main bus B to TLM INPUTS—BIO MED switch (MDC-20).		D-C main bus B		
	SERVICE PROPULSION SYSTEM circuit breakers					
	GAUGING group					
	MN A (5 amp)	Applies power from d-c main bus A to the following propellant utilization and gauging subsystem control unit circuits: a. Self-test b. Primary power supply only when SPS engine ignition driver relay is energized.				
	MN B (5 amp)	Applies power from d-c main bus B to propellant utilization and gauging subsystem control unit auxiliary power supply only when SPS engine ignition driver relay is energized.		+28 vdc		
	AC 1 (2 amp)	Applies power from a-c bus No. 1 to AC 1 contacts of SPS GAUGING switch on MDC-25.		115 vac 400 cps 0°C		
	AC 2 (2 amp)	Applies power from a-c bus No. 2 to AC 2 contacts of SPS GAUGING switch on MDC-25.				

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MDC-25 (Cont)	He VALVE group MN A (7.5 amp)	Applies power from d-c main bus A to the following: a. Left-hand SPS HELIUM switch (MDC-20) b. INJECT PRE-VALVES A switch (MDC-3) c. FCSM-G&N switch (MDC-2) d. FCSM-SCS switch (MDC-2)	N/A	+28 vdc	None	
		Applies power from d-c main bus B to the following: a. Right-hand SPS HELIUM switch (MDC-20) b. INJECT PRE-VALVES B switch (MDC-3) c. FCSM-G&N switch (MDC-2) d. FCSM-SCS switch (MDC-2).				
	GIMBAL MOTOR CONTROL group 1 - PITCH - 2 BAT A (15 amp)	Applies power from battery bus A to SPS GIMBAL MOTORS PITCH 1 switch on MDC-3.				
		Applies power from battery bus B to SPS GIMBAL MOTORS PITCH 2 switch on MDC-3.				
	1 - YAW - 2 BAT A (15 amp)	Applies power from battery bus A to SPS GIMBAL MOTORS YAW 1 switch on MDC-3.				
		Applies power from battery bus B to SPS GIMBAL MOTORS YAW 2 switch on MDC-3.				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-25 (Cont)	G&N SYNC switch	Provides manual maneuver capability in G&N attitude control mode.	SCS GROUP 2 MN A	D-C main bus A	None	When the G&N SYNC switch is returned to OFF and the rotation control is returned to detent, the G&N system will maintain S/C attitude within the selected deadband limits. This switch will not be used per procedural constraint.
	On (up)	Permits detent switch in rotational control to place CDUs in a follow mode.				
	OFF	Does not affect G&N attitude control mode.				
	SPS GAUGING switch		SPS— GAUGING AC 1 AC 2 (MDC-25)	A-C bus No. 1		Three-position toggle switch which controls application of a-c power to propellant quantity utilization and gauging system control unit. Power for control unit self-test circuitry is applied directly by switch. Power for propellant quantity measuring circuitry is applied only when engine ignition driver relay is energized by engine firing signal.
	AC 1	Applies a-c power to the following: a. Quantity gauging system control unit self-test circuitry. b. Normally open contacts of SPS engine ignition driver relay.				
	OFF	Removes all a-c power.				
	AC 2	Applies a-c power to the following: a. Quantity gauging system control unit self-test circuitry. b. Normally open contacts of SPS engine ignition driver relay.	N/A	A-C bus No. 2		
	AC SNSR SIG circuit breaker			115 vac 400 cps 3 phase		
	AC 1 (2 amp)	Applies power from a-c bus No. 1 to a-c over-undervoltage and overload sensing unit to AC INDICATORS switch (MDC-18).				
	AC 2 (2 amp)	Applies power from a-c bus No. 2 to a-c over-undervoltage and overload sensing unit and to AC INDICATORS switch (MDC-18).				

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MDC-25 (Cont)	REACTION CONTROL SYSTEM circuit breakers		N/A		None	
	PROP ISOL group MN A (10 amp)	<p>Applies power from d-c main bus A to the following:</p> <ul style="list-style-type: none"> <li>a. SM RCS quads B and D HELIUM 1, HELIUM 2, and PROPELLANT switches.</li> <li>b. CM RCS system A PROPELLANT switch.</li> <li>c. Microswitch in each isolation valve controlled by switches listed in steps a and b. Microswitch controls event indicator operation.</li> <li>d. RCS control box relay contacts which cause automatic closure of system A fuel and oxidizer isolation valves in the event of an abort initiation prior to T + 61 seconds.</li> </ul>				
	MN B (10 amp)	<p>Applies power from d-c main bus B to the following:</p> <ul style="list-style-type: none"> <li>a. SM RCS quads A and C HELIUM 1, HELIUM 2, and PROPELLANT switches.</li> <li>b. CM RCS system B PROPELLANT switch.</li> <li>c. Microswitch in each isolation valve controlled by switches listed in steps a and b. Microswitch controls event indicator operation.</li> </ul>				

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MDC-25 (Cont)	C/M - S/M TRANSFER group MN A (15 amp)	d. RCS control box relay contacts which cause automatic closure of system B fuel and oxidizer isolation valves in the event of an abort initiated prior to T + 61 seconds.	N/A	+28 vdc	None	
		Applies power from d-c main bus A to the following: a. RCS TRANSFER switch (MDC-16) b. C/M PROPELLANT JETT group LOGIC switch (MDC-8) c. C/M RCS HTRS switch RHFEB-200 d. C/M RCS He DUMP switch (MDC-26).				
		Applies power from d-c main bus B to the following: a. RCS TRANSFER switch (MDC-16) b. C/M PROPELLANT JETT group LOGIC switch (MDC-8) c. C/M RCS HTRS switch RHFEB-200 d. C/M RCS He DUMP switch (MDC-26).				
		Applies power from d-c main bus A to caution and warning system.				
	CAUT/WARN circuit breakers MN A (10 amp)  MN B (10 amp)	Applies power from d-c main bus B to caution and warning system.				
	EDS-1, 2, 3 circuit breakers BAT A (5 amp)	Applies d-c power from battery bus A to the EDS POWER switch (MDC-24).				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-25 (Cont)	BAT C (5 amp)	Applies d-c power from entry battery C to the EDS POWER switch (MDC-24).	N/A	+28 vdc	None	
	BAT B (5 amp)	Applies d-c power from battery bus B to the EDS POWER switch (MDC-24).				
	ELS-A, B circuit breakers BAT A - FLOAT BAT 3 (10 amp)	Applies d-c power from battery bus A to the following: a. ELS LOGIC switch (MDC-8) b. APEX COVER JETT switch (MDC-5) c. MAINDEPLOY switch (MDC-5) d. MAINDEPLOY switch (MDC-5) e. POST LANDING-FLOAT BAT - switch 3 (MDC-25).				
	BAT B (10 amp)	Applies d-c power from battery bus B to the following: a. ELS LOGIC switch (MDC-8) b. APEX COVER JETT switch (MDC-5) c. DROGUE DEPLOY switch (MDC-5) d. MAIN DEPLOY switch (MDC-5)				
MDC-26	FLOODLIGHTS controls PRIMARY rheostat Off Bright	Removes power from C/M primary floodlights. Indicates maximum floodlight brightness has been reached.	COUCH ATTEN MN A MN B FLOOD- LIGHTS (MDC-25)	D-C main buses A and B	None	FLOODLIGHTS controls on MDC-23, -26, and LEB-100 are functionally identical and each controls the floodlights in its respective area.  The rheostat control may be adjusted for desired brightness of primary floodlights.
	SECONDARY switch ON OFF	Illuminates secondary floodlights. Removes power from secondary floodlights.				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-26 (Cont)	POST LDG BEACON switch					
	LIGHT	Applies power to the beacon lights.	N/A	Beacon light battery	None	
	OFF	Removes power from the beacon lights.				
	POWER switch	Controls power to command pilot's module in audio center equipment	T/C — GROUP 4 (MDC-22)	Flight and postlanding bus		The audio center will not be activated unless the POWER switch is in PTT or VOX position.
	PTT	Applies d-c power to audio and control circuits.				Intercom capability when cobra cable PTT/CW switch is in C/W and transmit when switch is at PTT.
	OFF	Removes power from command pilot's audio center equipment module and controls.				
	VOX	a. Applies d-c power to audio and control circuits. b. Enables VOX control of mike amplifier by supplying ground to VOX circuitry.				VOX operation permits voice transmission and transmitter keying of intercom. HF recovery transceivers and voice recorder when cobra cable PTT/CW switch is at PTT.
	S-BAND switch		N/A	Audio center equipment		The S-BAND, HF, VHF-AM, and INTERCOM switches all control ground return paths for appropriate diode switching and isolation circuitry in the command pilot's module of the audio center equipment, to allow transmission and reception, or reception alone, of voice signals over selected equipment. The HF and VHF-AM switches also provide ground return paths for the HF and VHF-AM transmitter keying circuits when in the T/R position.
	T/R	No effect. S-band T/R function supplied by cobra cable PTT key.				
	OFF	Prevents command pilot from transmitting or receiving voice over USBE.				
	RCV	Enables command pilot to receive voice from USBE.				
	RCDR/HF switch					Provides power ground through audio center VOX circuit for HF transceiver transmit-receive relay and voice recorder power relay.
	T/R	a. Enables command pilot to transmit and receive voice over H-F transceiver when operating in AM or SSB mode. b. Enables voice recorder through VOX circuit.				
	OFF	Prevents command pilot from transmitting or receiving voice over H-F transceiver.				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-26 (Cont)	RCV	Enables command pilot to receive voice from H-F transceiver when operating in AM or SSB mode.	N/A	Audio center equipment	None	VHF-AM transmits, in addition to S-band voice, when cobra cable PTT key is closed. Cobra cable PTT/CW switch must be at PTT and audio center POWER switch must be at PTT.
	VHF AM switch	Enables command pilot to transmit and receive voice over VHF-AM transmitter-receiver when operating in T/R mode.				
	T/R	Prevents command pilot from transmitting or receiving voice over VHF-AM transmitter-receiver.				
	OFF	Enables command pilot to receive voice from VHF-AM transmitter-receiver.				
	RCV	Enables command pilot to receive voice from VHF-AM transmitter-receiver.				Audio center POWER switch must be at VOX to enable mike amplifier when cobra cable PTT/CW switch is at PTT.
	INTERCOM switch	Enables command pilot to transmit and receive voice over the intercom system.				
	T/R	Prevents command pilot from transmitting or receiving voice over intercom system.				
	OFF	Enables command pilot to receive voice from intercom system.				
	RCV	Increases or decreases sensitivity of voice-operated relay circuitry in command pilot audio center module.				These three control are thumb-wheel-type potentiometers which may be rotated upward or downward, as required.
	VOX SENS control	Increases or decreases level of audio signal received by command pilot from R-F equipment relative to that received from intercom bus.				
	INTERCOM BALANCE control	Increases or decreases level of audio signal from command pilot earphone amplifier to earphone.				Position 9 most sensitive.
	VOLUME control					

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
MDC-26 (Cont)	C/M RCS switch					
	He DUMP (up)  OFF (down)	Energizes relays required to activate C/M RCS helium purge operation.  De-energize relays.	RCS - C/M-S/M TRANSFER MN A MN B (MDC-25)	D-C main buses A and B	None	Two-position guarded toggle switch which provides backup capability for initiating helium purge operation in the event of C/M PROP JETT PURGE switch failure (MDC-8). The switch receives power directly from the circuit breakers.
LEB-100	LIGHTING controls					
	FLOODS group					
	PRIMARY rheostat					
	OFF	Removes power from C/M primary floodlights.	COUCH ATTEN MN A MN B	D-C main buses A and B	None	FLOODLIGHTS controls on MDC-23, -26, and LEB-100 are functionally identical and each controls the floodlights in its respective area.
	BRIGHT	Indicates maximum floodlight brightness has been reached.	FLOOD- LIGHTS (MDC-25)			The rheostat control may be adjusted for desired brightness of primary floodlights.
	SEC switch					
	ON	Illuminates secondary floodlights.				
	OFF	Removes power from secondary floodlights.				
	CLOCKS switch					
	BRT	Brightly illuminates the integral lighting for the mechanical clocks on LHFEB-306.				
	OFF	Disconnects power from the lighting circuit to the clocks.				
	DIM	Dimly illuminates the integral lighting for the mechanical clocks on LHFEB-306.				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-101	IMU-CDU DIFFERENCE indicator	Displays the difference between the IMU gimbal angles and the CDU shaft angles in degrees.	G&N-IMU MN A MN B (MDC-22)	D-C main buses A and B	None	A three-dial panel meter. The signals applied to the meter are the demodulated outputs of the CDU single speed receivers. Depending upon the IMU mode, the differences shown can represent the following: a. Misalignment of the IMU b. Error in the orientation of the spacecraft. c. Error in the CDU display of actual gimbal angles.
	TRANSFER switch	Controls selection of ISS operating modes.				SPST toggle switch
	MANUAL	Enables manual selection of ISS operating modes through the use of MODE switches.				
	COMPUTER	Enables AGC selection of ISS operating modes by setting mode relays directly.				
	MANUAL ALIGN switch	Causes the IMU gimbals to align CDU angles.				SPST momentary contact pushbutton. Used in conjunction with CDU MAN mode pushbutton to coarse align the IMU gimbals.
	MODE switches	Allow selection and display of ISS operating modes.				SPST illuminates pushbutton switches. Computer controlled when TRANSFER switch is in COMPUTER position. Manually controlled when TRANSFER switch is in MANUAL position.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-101 (Cont)	ZERO ENC	Selects zero encoder mode of ISS operation. This mode sets the shafts and encoders of the CDUs and CDU registers in the computer to zero.	G&N—IMU MN A MN B (MDC-22)	D-C main buses A and B	None	CDUs must be zeroed whenever the G&N system is turned on.
	COARS ALIGN	Selects coarse align mode of IMU operation. This mode positions the stable member of the IMU. Selects coarse align mode of ISS operation. This mode positions the stable member to within 1.5° of desired inertial reference attitude.				In this mode, the CDUs are driven to angles commanded by the AGC. These angles define an inertial reference.
	FINE ALIGN	Selects fine align mode of ISS operation. This mode completes stable member alignment to desired inertial reference attitude.				Upon completion of the fine align mode, the stable member is fine aligned to an inertial reference and the CDU readouts indicate gimbal angles relative to that reference.
	CDU MAN	Selects manual CDU mode of ISS operation. This mode provides for backup-manual alignment of the stable member. Stable member drives to CDU angles when MANUAL ALIGN switch is depressed.				Actuation of CDU MAN switch energizes a relay which removes the excitation to the CDU motors to lock the CDUs in position.
	ATT CONT	Selects attitude control mode of IMU operation. Selects attitude control mode of ISS operation. This mode provides attitude and velocity change sensing with respect to the space stabilized, stable member.				The attitude error signals generated in this mode represent the difference between IMU gimbal angles and CDU angles.
LEB-102	ENTRY	Selects entry mode of IMU operation. This mode is similar to attitude control mode; however, the gain of the roll control loop is increased by a factor of 16 to increase roll rate and decrease response time.			None	This mode is used during spacecraft entry into the earth atmosphere.
	CDU angle display readouts 2X TRUNNION, SHAFT ANGLE, OUTER GIMBAL (ROLL), INNER GIMBAL (PITCH), MIDDLE GIMBAL (YAW)	Provide visual representation of ICPU and OCDU angles.				Drum-type readout. Reads down to 0.001 degree. Five such readouts are on this panel: two for optics and three for inertial CDUs.

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LEB-103	G&N condition lights	Warning lights denote detected malfunction.	G&N—IMU MN A MN B (MDC-22)	D-C main buses A and B		Yellow caution lights.
	PGNS	Indicates an IMU, CDU accelerometer and/or AGC failure.			CG5005X (Error detect)	
	AGC PWR FAIL	Indicates a failure in the Apollo guidance computer power supply.			CG5030X (Computer power fail light)	
	IMU FAIL	Indicates a failure in the inertial measurement unit.			CG5001X (IMU fail)	
	CDU FAIL	Indicates a failure in one or more of the coupling display units.			CG5002X (CDU fail)	
	ACCEL FAIL	Indicates a failure in one or more of the PIPAs.			CG5000X (PIPA fail)	
	GIMBAL LOCK	Indicates a potential gimbal lock condition in the IMU (middle gimbal angle is greater than $\pm 60^\circ$ with respect to outer gimbal).			CG5003X (Gimbal lock warning)	
	IMU TEMP	Indicates that the IMU temperature is out of tolerance, i.e., exceeds normal temperature by $\pm 4^\circ\text{F}$ (if IMU TEMP MODE switch is in AUTO OVERRIDE or PROPORTIONAL positions).			CG5006X (IMU temp light)	
	ZERO ENCODER	Indicates that the CDU encoders are being zeroed; lamp is extinguished after all encoders have been zeroed. (Remains illuminated for approximately 30 seconds. If AGC commanded zero encode mode, indicator may be illuminated for approximately 60 seconds.)			CG5007X (Zero encoder light)	White light.
	IMU DELAY	IMU coarse alignment to CDU angles taking place. Stable member is caged. Remains illuminated for approximately 100 seconds.			CG5008X (IMU delay light)	White light. Illuminates only at initial IMU turn-on or immediately after switching from standby operation.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-103 (Cont)	MASTER ALARM light	Red light illuminates to alert crewmembers at lower equipment bay of malfunction or out-of-tolerance condition. This is indicated by illumination of applicable system status lights on MDC-10 or -11.	CAUT/ WARN MN A MN B (MDC-25)	D-C main buses A and B	CS0150X (Master caution-warning on)	Upon illumination of MASTER ALARM light, the MASTER ALARM switch-lights on MDC-3 and -18 are simultaneously illuminated and an audio tone is sent to each headset.  The MASTER ALARM light does not contain an integral switch. Light may be extinguished only by pressing the MASTER ALARM switch-light on MDC-3 or -18.
LEB-104	Sextant	Optical instrument for measuring the angle between two objects.	None	None	None	The SXT is a dual line-of-sight instrument used to determine the following: a. The angle between a landmark and a star. b. The angle between a star line of sight and the navigation base. c. Tracking an unknown landmark.  This information is used by the AGC for the following: a. Determine spacecraft position. b. Calculate required $\Delta V$ corrections. c. To fine align the IMU.  The SXT has a 1.8° field of view with a magnification of 28.  The scanning telescope has a 60° field of view and a 1X magnification (long relief eyepiece = 0.6X).
	Scanning telescope	Optical instrument used for the following: a. Tracking a landmark in earth orbit. b. Identifying and centering a star within the sextant field of view.				
	TRUNNION control	Enables manual positioning of the trunnion angles.				These controls are manually operated by means of a universal tool. They are used in the event of optics electronic failure.
	SHAFT control	Enables manual positioning of the shaft angles.				
	TRUNNION ANGLE display	Provides a mechanical readout of the SCT trunnion angle that is commanded manually or by the computer.				Drum-type readouts in degrees, mechanically connected to the scanning telescope (SCT) trunnion and shaft drives, respectively. (SXT angles are identical.)
	SHAFT ANGLE display	Provides a mechanical readout of the SCT shaft angle that is commanded manually or by the computer.				

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LEB-105	Optics hand controller	Provides electrical commands to the optics shaft and trunnion drive motors.	G&N-OPTICS MN A MN B (MDC-22)	D-C main buses A and B	None	SP4T, five-position switch spring-loaded to center OFF position. direction of target movement with respect to controller movement depends upon mode selected by CONTROLLER MODE switch. Rate of image movement is proportional to amount of hand controller movement.
	CHECK COOLANT switch	When pressed, applies power to floodlamps behind the display and control panel. Enables the crew to view the IMU quick-disconnect couplings through CHECK COOLANT windows.				Pushbutton switch, momentary contact.
	CHECK COOLANT windows (two)	Permit observation of IMU coolant supply system quick-disconnect couplings for detecting leaks.	None	None		
	AGC code numbers display (not shown)	Provides the crew with a quick reference for computer code numbers.				Panel inscribed, nonreplaceable.
	MARK switch	Supplies an interrupt signal to the AGC which commands it to read the optics CDU angles, the time, and the IMU gimbal angles (if the IMU is operating).	G&N-OPTICS MN A MN B (MDC-22)	D-C main buses A and B		Pushbutton, SPST, momentary-contact switch. If MARK is satisfactory, computer proceeds normally. If MARK is unsatisfactory, flight crew inhibits computer processing of data by making DSKY entry of V52E.
	PANEL BRIGHTNESS control	Provides adjustment of the illumination level of all integrally lighted G&N system controls and displays. In addition, the control provides power to the lamp in the THRUST ON switch.				Thumbwheel potentiometer.
	CHECK MODE LAMPS switch	Applies power to all MODE indicators on the IMU control panel LEB-101.				Pushbutton, SPST, momentary-contact switch. Used to check operation of the MODE lamps.
	CHECK CONDITION LAMPS switch	Applies power to all condition (caution and warning) lamps on panel LEB-103.				Pushbutton, SPST, momentary-contact switch. Used to check the operation condition of the condition lamps.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-105 (Cont)	CONDITION LAMPS switch				None	
	ON	Applies d-c power to G&N condition lamps.	G&N-IMU MN A MN B (MDC-22)	D-C main buses A and B		SPST toggle switch.
	OFF	Removes d-c power from lamps.				
	ATTITUDE IMPULSE group					
	Attitude impulse control	A control stick used to apply small rotational thrust impulses to the spacecraft by means of the service module reaction jets.	SCS — GROUP 1 AC 1 AC 2 (MDC-25)	Essential bus		SP6T, seven-position switch, spring-loaded to center off. The control is used to apply one or any combination of pitch, roll, or yaw minimum thrust impulses to the S/C providing rate damping impulses of 2.4 arc-minutes/second/pulse or less. One pulse is produced each time the control is moved from the center position.
	ENABLE switch	Enables the attitude impulse control.				Toggle-type, solenoid-held-to-on microswitch. The SCS must be in the G&N or SCS attitude control modes to enable solenoid holding. Attitude impulse is not enabled in the SCS local vertical mode. To enable the attitude impulse control circuit, the LIMIT CYCLE switch must also be ON.
	ON	Supplies a signal to the G&N and SCS systems which disables the active S/C attitude control mode, allowing the S/C to drift freely, and enables the attitude impulse control.				
	OFF	Disables the attitude impulse control.				
	IMU TEMP MODE group					
	Mode switch	Enables the crew to select any one of the four modes of IMU temperature controls.	G&N IMU HTR MN A MN B (MDC-22)	D-C main buses A and B		Rotary, four-position, three-wafer switch.
	PROPORTIONAL	Temperature control is furnished by same control circuit used in AUTO/OVERRIDE mode.				PROPORTIONAL mode is used if a malfunction occurs in the temperature indicating circuit, causing cycling to the EMERGENCY mode.
	BACKUP	Temperature control is furnished by temperature sensing circuits.				BACKUP mode is used if a malfunction occurs in the normal control circuit. In this mode, the IMU TEMP light will illuminate when the heaters are off and will extinguish when the heaters are on. MSFN must monitor

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-105 (Cont)	AUTO OVERRIDE	Normal mode of temperature control. If IMU temperature exceeds normal tolerances by $\pm 4^{\circ}\text{F}$ , system automatically switches to emergency mode and IMU TEMP light illuminates.	G&N IMU HTR MN A MN B (MDC-22)	D-c main buses A and B	None	the IMU temperature. Manual switching to emergency mode is necessary if the temperature becomes excessive.
						When a malfunction occurs, the temperature alarm relays turn off the control heaters. Emergency heaters continue to operate under the control of an emergency mercury thermostat. When the temperature returns to within $1^{\circ}\text{F}$ of normal, the IMU TEMP light extinguishes and the system switches back to the normal control mode.
	EMERGENCY	IMU temperature is controlled to approximately $130^{\circ}\text{F}$ by means of mercury thermostat and emergency heaters.				A thermostat provides overheat protection for the IMU by opening the emergency heater circuit when the temperature exceeds $130^{\circ}\text{F}$ . When this temperature drops below $128^{\circ}\text{F}$ , the thermostat closes the circuit to reactivate the heaters.
		ZERO switch				Pushbutton, DPST, momentary-contact switch.
	GAIN switches	Used to check temperature alarm circuit.				
		IRIG				Pushbutton, momentary-contact switch. When it is pressed, the IMU TEMP indicator (LEB-103) should be illuminated. If not, a malfunction exists in the system.
		PIPA				
	MAP AND DATA VIEWER group	None	None	None		Function deleted as a result of map and data viewer deactivation.
	OPTICS group					
	SLAVE TELESCOPE switch					
	STAR LOS	Slaves SCT trunnion axis to SXT trunnion.	G&N OPTICS MN A MN B (MDC-22)	D-C main buses A and B		Single pole, three-position toggle switch

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-105 (Cont)	LANDMARK LOS 0°	Drives SCT trunnion to zero independently of CDU trunnion.	G&N OPTICS MN A MN B (MDC-22)	D-C main buses A and B	None	Zero position is parallel to SXT shaft axis.
	OFFSET 25°	Drives telescope trunnion to 25° offset from shaft axis.				This will bring the star and landmark within the 60° field-of-view of the SCT, while rotating about the shaft axis.
	OPTICS HOLD	Opens input to motors to prevent CDU creep.				SPST, toggle switch.
	Mode switch	Selects optics mode of operation.				Rotary, three-position switch.
	ZERO OPTICS	Optics and CDU resolvers are driven to zero. AGC register is set to all zeros.				Completed in approximately 60 seconds.
	MANUAL	Normal operating position enabling crew to position optics by means of optics hand controller.				In this position, the crew may select either the DIRECT or RESOLVED controller mode of operation.
	COMPUTER	Optics are automatically positioned by the AGC. Panel-mounted controls are disabled.				
	CONTROLLER SPEED switch	Provides attenuation of shaft and trunnion slew commands from optics hand controller.				Single-pole, three-position toggle switch. Attenuated output is applied to the MODE switch.
	HI MED LOW	Direct Mode Maximum Drive Rates  Trunnion                      Shaft 8.8°/sec                      17.3°/sec 1.05°/sec                      2.06°/sec 0.105°/sec                      0.206°/sec  Resolved Mode Maximum Drive Rates  Trunnion                      Shaft 8.8°/sec                      8.8°/sec 1.05°/sec                      1.05°/sec 0.105°/sec                      0.105°/sec				
	CONTROLLER MODE switch	Controls control stick output configuration.				SPDT, two-position, toggle switch.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-105 (Cont)	DIRECT	Applies control movements directly to CDUs. Right/left movement commands shaft rotation. Up/down movement commands trunnion angle increase/decrease.	G&N— OPTICS MN A MN B (MDC-22)	D-C main buses A and B	None	Target moves about arcs with speed of target movement varying with magnitude of angle.
	RESOLVED	Applies control stick movements to angular resolving circuits before applying commands to the CDUs.				Target moves horizontally and vertically at a linear rate.
LEB-106	Alarm condition indicators	Indicate abnormal conditions of computer operation.	G&N COMPUTER MN A MN B (MDC-22)	D-C main buses A and B		
	PROG ALM	AGC program error detected.			CG5020X (AGC alarm 1)	Observe REGISTER displays for numerical flag denoting malfunction.
	COUNTER FAIL	Counter increment instruction not executed or not completed within 10 msec of initiation.			CG5026X (AGC alarm 7)	If malfunction is counter-increment not completed within 10 msec, the TC TRAP indicator will illuminate.
	RUPT LOCK	No interrupt within 80 msec or interrupt not completed within 10 msec.			CG5028X (AGC alarm 9)	
	TC TRAP	Transfer control not executed within 10 msec or not completed within 10 msec.			CG5029X (AGC alarm 10)	
	SCALER FAIL	100-pps signal from scaler A of computer timing section failed.			CG5024X (AGC alarm 5)	
	PARITY FAIL	Parity error exists in data word from memory.			CG5025X (AGC alarm 6)	
	TM FAIL	Telemetry data rate incorrect or transmission incorrect.			CG5022X (AGC alarm 3)	
	CHECK FAIL	Incorrect DSKY operation attempted.			CG5023X (AGC alarm 4)	
	KEY RLSE	Computer program cannot proceed until operator releases DSKY control.			CG5027X (AGC alarm 8)	Not a failure. Operator will press KEY RELEASE pushbutton. Computer will resume computation.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-106 (Cont)	ACTIVITY lights	Indicates activity the computer is presently engaged in.	G&N COMPUTER MN A MN B (MDC-22)	D-C main buses A and B	CG5021X (AGC alarm 2)	
	UPTL	Computer is receiving information from telemetry up-data link.				
	COMP	Computer is engaged in computation.				
	PROGRAM indicator	A two-digit display, indicating the number of the program (major mode) presently in progress.				
	VERB indicator	A two-digit display, indicating verb code selected.				
	NOUN indicator	A two-digit display, indicating noun code selected.				
	REGISTER 1 indicator	Displays contents of selected register or memory location. First component of extended data word, if applicable.				
	REGISTER 2 indicator	Displays contents of selected register or memory location. Second component of extended data word, if applicable.				
	REGISTER 3 indicator	Displays contents of selected register or memory location. Third component of extended data word, if applicable.				
	BRIGHTNESS control	Varies brightness of electro-luminescent data displays: REGISTER 1, REGISTER 2, and REGISTER 3.				
	KEY RELEASE pushbutton	Enables program control of DSKY. Releases operator control of DSKY circuits.			None	On-board data provides definition of PROGRAM, NOUN, and VERB digits.
	TEST ALARM pushbutton	Illuminates the alarm displays for bulb test.				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-106 (Cont)	ERROR RESET pushbutton	Resets alarm light relays. AGC recycles to start of current operation.	G&N COMPUTER MN A MN B (MDC-22)	D-C main buses A and B	None	Verifies alarms. Alarms triggered by transients should not repeat.  Pushbutton-type switches (selectors). Each key generates a specific 5-bit key code denoting the instruction or number being selected.
	Keyboard switches	Provide for entering data into or commanding operations of the AGC.				
	CLEAR	Places all zeros (logic 0s) in register being loaded.				
	VERB	Prepares computer to accept next two digits as verb code.				
LEB-107	NOUN	Prepares computer to accept next two digits as noun code.	G&N COMPUTER MN A MN B (MDC-22)	D-C main buses A and B	None	SPDT, toggle switch  In STANDBY, AGC maintains timing signals and other circuits necessary to restart. STANDBY operation is used to conserve electrical power.
	ENTER	Transfers contents of input register to central processor and initiates execution of instructions.				
	+	Denotes data to follow has positive decimal value.				
	-	Denotes data to follow has negative decimal value.				
LEB-120	0 to 9	Enters binary equivalent of key pressed.	GAS ANAL— AC 1 (MDC-22)	A-C bus No. 1 (ØA)		The gas chromatograph (GFE) is serviced and installed by ground support personnel prior to flight crew ingress. The unit operates on 80-minute cycles, during which it identifies 28 gas components.
	AGC MODE switch ON STANDBY	Applies normal power to AGC. Applies power timing section of AGC.				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-120 (Cont)	CABIN AIR/AUTO/ SUIT AIR switch	Selects C/M cabin atmosphere for gas component sampling.	GAS ANAL— AC 1 (MDC-22)	A-C bus No. 1 (0A)	CTO 108K (Gas analysis suit and cabin)	Switch set to CABIN AIR position on command from MSFN.
	CABIN AIR	Permits suit circuit and C/M cabin atmospheres to be alternately sampled for gas components.				Normal position of switch.
	AUTO	Selects suit circuit atmosphere for gas component sampling.				Switch set to SUIT AIR position on command from MSFN.
	SUIT AIR					
LEB-150	START/OFF/ PREHEAT switch	Applies a-c power to operational portion of gas chromatograph.	N/A	Pyro battery A +23 vdc	None	Oven requires 7 watts for preheat period and 5 watts during operation.
	START	Removes a-c power from warmup oven and operational portion of gas chromatograph.				Normal position of switch after completion of preheat operation.
	OFF	Applies a-c power to oven for required preheating prior to unit being placed in operation.				A minimum of 30 minutes warmup is required before switch is set to START position.
	PREHEAT	Push-type switch for use during bench calibration only.				
LEB-150	AMPL-CAL switch		N/A	Pyro battery A +23 vdc	None	Thermal, push-pull, manual reset type circuit breakers with the amperage rating of each denoted by a white placard.  Normally closed in flight. Opened if pyro battery A fails.
	Pyro battery circuit breakers PYRO A group SEQ A (20 amp)	Applies d-c power from pyro battery A to the MESC pyro bus when the MASTER EVENT SEQ CONT—switch A or B (MDC-24) is in the PYRO ARM position, and to the open contacts of the C/M RCSC pyro arm relay in the MESC. The relay is energized when the MASTER EVENT SEQ CONT—switch A or B (MDC-24) is in the PYRO ARM position to arm the pyro bus in the C/M RCSC. Applies pyro battery A voltage to DC INDICATORS switch.				
	BAT A TO PYRO BUS TIE (20 amp)	Applies d-c power from entry battery A to above sequencer circuits, and entry battery A voltage to PYRO BAT A position of DC INDICATORS switch.	N/A	Entry battery A +28 vdc	None	Normally open in flight. Closed if pyro battery A fails.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LEB-150 (Cont)	PYRO B group SEQ B (20 amp)	Applies d-c power from pyro battery B to the MESC pyro bus when the MASTER EVENT SEQ CONT—switch A or B (MDC-24) is in the PYRO ARM position, and to the open contacts of the C/M RCSC pyro arm relay in the MESC. The relay is energized when the MASTER EVENT SEQ CONT—switch A or B (MDC-24) is in the PYRO ARM position to arm the pyro bus in the C/M RCSC. Applies pyro battery B voltage to DC INDICATORS switch.	N/A	Pyro battery B +23 vdc	None	Normally closed on flight. Open if pyro battery B fails.
	BAT B TO PYRO BUS TIE (20 amp)	Applies d-c power from entry battery B to above sequencer circuits. Applies entry battery B voltage to PYRO BAT B position of DC INDICATORS switch.		Entry battery B +28 vdc		Normally open in flight. Closed if pyro battery B fails.
	BAT CHGR-BAT C circuit breaker (5 amp)	Applies d-c power from battery C to: a. BATTERY CHARGER selector switch. b. D-C INDICATORS selector switch.		+28 vdc	CC0212V (D-C voltage postlanding battery)	
	BAT C PWR - POSTLANDING ENTRY circuit breaker (100 amp)	a. Applies d-c power from battery C through 25-amp POSTLDG - BAT C circuit breaker to flight and post-landing bus. b. Applies d-c power to 80-amp MAIN A - BAT C and MAIN B - BAT C circuit breakers.			CC0224C (D-C current postlanding battery)	
	BAT B PWR-ENTRY circuit breaker (100 amp)	Applies d-c power from entry battery B to battery bus B			CC0223C (D-C current battery B)	
	BAT A PWR-ENTRY circuit breaker (100 amp)	Applies d-c power from entry battery A to battery bus A.			CC0222C (D-C current battery A)	

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
RHFEB-200	C/M RCS HTRS switch On (up)  OFF	Activates relays which apply +28 vdc to the direct coils of all C/M RCS engine solenoid valves.  Deactivates relays which remove +28 vdc from the direct coils of all C/M RCS engine solenoid valves.	RCS — HEATERS A MN B B MN A (MDC-21)	+28 vdc	None	Two-position toggle switch, used to pre-heat all C/M RCS engine valves in order to preclude propellant freezing when system is pressurized prior to entry.  Switch is enabled by CM PROP JETT-LOGIC switch (MDC-8) in the ON (up) position.
	DC VOLTS meter (auxiliary)	Indicates d-c voltage of selected measurement points.	N/A	Instrumentation signal conditioners	Refer to TEST SELECT switch (RHFEB-97)	Meter functions in conjunction with FUNCTION SELECT and TEST SELECT switches located directly below meter. Meter range is 0 to 5 vdc.  FUNCTION SELECT switch in conjunction with the TEST SELECT switch makes possible 24 measurement points for the Aux DC VOLTS meter.
	FUNCTION SELECT switch	Selects A or B wafer of TEST SELECT switch.				
	A	Connects Aux DC VOLTS meter to wafer A of TEST SELECT switch.				
	OFF	Disconnects Aux DC VOLTS meter from circuit.				
	B	Connects Aux DC VOLTS meter to wafer B of TEST SELECT switch.				
	TEST SELECT switch	Selects two groups of 12 measurements, depending on position of FUNCTION SELECT switch, A or B.  Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates output pressure of fuel cell No. 1 nitrogen regulator.  Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates temperature of C/M oxidizer valve, -P engine (No. 2) system A.				TEST SELECT switch has two independent wafers, each containing 12 contacts.  N <sub>2</sub> pressure range is 0 to 75 psia.  SC2060P (N <sub>2</sub> pressure F/C 1 regulated)  CR2205T (Temp ox. valve -P engine system A)  Temperature range is -50° to +250°F.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
RHFEB-200 (Cont)	2 (A)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates output pressure of fuel cell No. 2 nitrogen regulator.	N/A	Instrumentation signal conditioners	SC2061P (N <sub>2</sub> pressure F/C 2 regulated)	N <sub>2</sub> pressure range is 0 to 75 psia.
	2 (B)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates temperature of C/M oxidizer valve, +Y engine (No. 7) system B.			CR2203T (Temp ox. valve +Y engine system B.)	Temperature range is -50° to +250°F.
	3 (A)	Applies a d-c measurement to Aux DC VOLTS meter which indicates output pressure of fuel cell No. 3 nitrogen regulator.			SC2062P (N <sub>2</sub> pressure F/C 3 regulated)	N <sub>2</sub> pressure range is 0 to 75 psia.
	3 (B)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates temperature of C/M oxidizer valve, -P engine (No. 4) system B.			CR2204T (Temp ox. valve -P engine system B.)	Temperature range is -50° to +250°F.
	4 (A)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates output pressure of fuel cell No. 1 oxygen regulator.			SC2066P (O <sub>2</sub> pressure F/C 1 regulated)	O <sub>2</sub> pressure range is 0 to 75 psia.
	4 (B)	Applies a d-c measurement voltage to DC VOLTS meter which indicates temperature of C/M oxidizer valve cw engine (No. 11) system B.			CR2206T (Temp ox. valve cw engine system B.)	Temperature range is -50° to +250°F.
	5 (A)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates output pressure of fuel cell No. 2 oxygen regulator.			SC2067P (O <sub>2</sub> pressure F/C 2 regulated)	O <sub>2</sub> pressure range is 0 to 75 psia.
	5 (B)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates PIPA temperature.			CG2300T (PIPA temperature)	Temperature range TBD.
	6 (A)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates output pressure of fuel cell No. 3 oxygen regulator.			SC2068P (O <sub>2</sub> pressure F/C 3 regulated)	O <sub>2</sub> pressure range is 0 to 75 psia.

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RHFEB-200 (Cont)	6 (B)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates IRIG temperature.	N/A	Instrumentation signal conditioners	CG230IT (IRIG temperature)	Temperature range TBD.
	7 (A)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates output pressure of fuel cell No. 1 hydrogen regulator.			SC2069P (H <sub>2</sub> pressure F/C 1 regulated)	H <sub>2</sub> pressure range is 0 to 75 psia.
	7 (B)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates IMU heater current.			CG2302C (IMU heater current)	IMU heater current range is from 0 to 5 amperes.
	8 (A)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates output pressure of fuel cell No. 2 hydrogen regulator.			SC2070P (H <sub>2</sub> pressure F/C 2 regulated)	H <sub>2</sub> pressure range is 0 to 75 psia.
	8 (B)	Applies a d-c measurement to Aux DC VOLTS meter which indicates IMU blower current.			CG2303C (IMU blower current)	IMU blower current range is from 0 to 5 amperes.
	9 (A)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates output pressure of fuel cell No. 3 hydrogen regulator.			SC2071P (H <sub>2</sub> pressure F/C 3 regulated)	H <sub>2</sub> pressure range is 0 to 75 psia.
	9 (B)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates pressure of battery compartment manifold.			CC0188P (Press. bat. compartment manifold)	Battery compartment manifold pressure range is 0 to 18 psia.
	10 (A)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates temperature of F/C No. 1 radiator outlet.			SC2087T (Temp F/C 1 radiator outlet)	F/C 1 radiator outlet temperature range is -50° to +300°F.
	10 (B)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates temperature of ECS radiator inlet.			SF0665T (ECS radiator inlet temp)	ECS radiator inlet temperature sensor range is +60° to +150°F. Minimum inlet temperature is 75°F.
	11 (A)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates temperature of F/C No. 2 radiator outlet.			SC2088T (Temp F/C 2 radiator outlet)	F/C 2 radiator outlet temperature range is -50° to +300°F.

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RHFEB-200 (Cont)	11 (B)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates temperature of C/M oxidizer valve, ccw engine (No. 12) system A.	N/A	Instrumentation signal conditioner)	CR2201T (Temp ox. valve ccw engine system A)	Temperature range is -50 to +250°F.
	12 (A)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates temperature of F/C No. 3 radiator outlet.			SC2089T (Temp F/C 3 radiator outlet)	F/C 3 radiator outlet temperature range is -50° to +300°F.
	12 (B)	Applies a d-c measurement voltage to Aux DC VOLTS meter which indicates temperature of C/M oxidizer valve, -Y engine (No. 8) system A.			CR2202T (Temp ox. valve -Y engine system A)	Temperature range is -50° to +250°F.
RHFEB-207	SCIENTIFIC EQUIPMENT receptacle switch  ON  OFF	Applies d-c power from nonessential bus No. 2 to SCIENTIFIC EQUIPMENT receptacle for M09A experiment 16 mm sequence camera.  Removes d-c power from SCIENTIFIC EQUIPMENT receptacle.	SCIEN EQUIP. HATCH (MDC-22)	+28 vdc	None	
RHEB-201	WASTE MANAGEMENT panel  OVBD DRAIN valve  DUMP	Connects WMS overboard dump line from selector valve to outside atmosphere, permitting dumping urine and fecal odors overboard.	N/A	N/A	None	This shutoff valve is manually controlled by bar knob.  The valve is operated in conjunction with the SELECTOR valve. Valve is set to DUMP position after setting SELECTOR valve to URINE FECES position. Upon completion of dumping or venting operation, OVBD DRAIN valve is set to OFF position before SELECTOR valve is set to OFF position.
	OFF  SELECTOR valve	Closes WMS overboard dump line to outside atmosphere.				This valve is manually controlled by bar knob.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
RHEB-201 (Cont)	URINE FECES	a. Connects waste management dump line to overboard dump line. b. Closes switch that applies a-c power to WMS blower.	ECS-CABIN AIR FAN-1-AC 1 ØA ØB ØC (MDC-22)	A-C bus No. 1	None	Blower operation in this valve position is not functional due to WMS modifications.  Valve is placed to URINE FECES position for dumping urine collected in the Urine Sample Volume Measurement System (USVMS), or for venting odors originating during fecal canister usage.  This valve position is selected in conjunction with the OVBD DRAIN valve. Valve is set to URINE FECES position before setting OVBD DRAIN valve to DUMP position. Upon completion of dumping or venting operation, SELECTOR valve is set to OFF position after OVBD DRAIN valve is set to OFF position.  With valve to VACUUM position, WMS blower is activated and blower exhaust is directed into C/M cabin.
	VACUUM	a. Connects vacuum cleaner line to WMS blower. b. Closes switch that applies a-c power to WMS blower.	None	None		
	OFF	a. Closes all valve ports, deactivating waste management system. b. Removes a-c power from WMS blower.				
RHEB-202	WASTE MANAGEMENT ACCESS panel BATTERY VENT valve VENT CLOSE	Permits gases generated by C/M batteries to be vented into the urine/water dump line.  Shuts off the venting of C/M batteries into the urine/water dump line.	N/A	N/A	None	This valve is manually controlled by a bar knob.  Normal position of valve is VENT to dump overboard gases generated by C/M batteries.  Valve is closed in event of battery vent system leakage, which would permit C/M atmosphere leakage to space.
RHEB-203	MAIN A circuit breakers BAT BUS A (80 amp)	Applies d-c power from battery bus A to d-c main bus A through contacts of main bus tie bat A motor switch.	N/A	+28 vdc	None	

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
RHEB-203 (Cont)	BAT C (80 amp)	Applies d-c power from battery C to d-c main bus A through contacts of main bus tie bat B motor switch.	N/A	+28 vdc	None	These circuit breakers remain dis-engaged during flight and are engaged (pushed in) prior to CSM separation.
	MAIN B circuit breakers					
	BAT C (80 amp)	Applies d-c power from battery C to d-c main bus B through contacts of main bus tie bat A motor switch.				
	BAT BUS B (80 amp)	Applies d-c power from battery bus B to d-c main bus B through contacts of main bus tie bat B motor switch.				
	POST LDG circuit breakers					
	BAT BUS A (25 amp)	Applies d-c power from battery bus A to flight and postlanding bus.				
	BAT BUS B (25 amp)	Applies d-c power from battery bus B to flight and postlanding bus.				
	BAT C (25 amp)	Applies d-c power from 100-amp BAT C PWR circuit breaker to flight and postlanding bus.				
	MAIN A (10 amp)	Applies power from d-c main bus A to flight and postlanding bus.				
	MAIN B (10 amp)	Applies power from d-c main bus B to flight and postlanding bus.				
	INVERTER PWR circuit breakers					
	NO. 1 MN A (70 amp)  NO. 2 MN B (70 amp)	Applies power from d-c main bus A to inverter No. 1.  Applies power from d-c main bus B to inverter No. 2.				

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## CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
RHEB-203 (Cont)	NO. 3 group MN A (70 amp)  MN B (70 amp)	Applies power from d-c main bus A to inverter No. 3.  Applies power from d-c main bus B to inverter No. 3.	N/A	+28-vdc	None	
RHEB-204	INST PWR CONT circuit breaker  ESSENTIAL group 1 (7.5 amp)  2 (7.5 amp)  3 (7.5 amps)  4 (5 amp)  NON ESSENTIAL group 5 (5 amp) 6 (5 amp) 7 (5 amp) 8 (10 amp)  9 (10 amp)  10 (10 amp)	Applies +28-vdc power to RCS and structural operational instrumentation.  Applies +28-vdc power to ELS, EPS, and ECS surge tank operational instrumentation.  Applies +28-vdc power to operational instrumentation in S/M. (Spare)  (Spare) (Spare) (Spare)  Applies 28-vdc power to flight qualification instrumentation.  Applies 28-vdc power to flight qualification instrumentation and to ECS radiator outlet temperature sensors. (Spare)	INSTRUMENTS—ESS MN A and/or MN B (MDC-22)          INSTRUMENTS—NONESS (MDC-22)       INSTRUMENTS—NONESS (MDC-22)	D-C main bus A or d-c main bus B                       Non-essential bus No. 1                      Non-essential bus No. 1	None                      None	
RHEB-205	UPRIGHTING SYSTEM circuit breakers  COMPR NO. 1 (25 amp)  COMPR NO. 2 (25 amp)	Applies d-c power from battery bus A to the control motor switch of compressor No. 1.  Applies d-c power from battery bus B to the control motor switch of compressor No. 2.	N/A	+28-vdc	None	The compressors are turned on and off by manual actuation of the POST LANDING—FLOAT BAG switches on MDC-25.  These circuit breakers remain disengaged during flight and are engaged only after landing.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
RHEB-206	ECS STEAM DUCT HTR circuit breakers  MN A (5 amp)  MN B (5 amp)	Applies power from d-c main bus A to the following: a. Steam duct heater b. Urine/water dump nozzle heater.  Applies power from d-c main bus B to the following: a. Steam duct heater b. Urine/water dump nozzle heater.	N/A	+28 vdc	None	There are no switches to control the operation of the heaters. When the circuit breakers are activated, power is applied directly to corresponding 3-watt heating elements of the steam duct heaters, and to the 5, 7-watt urine/water dump nozzle heater. Normally, both the steam duct and urine/water dump nozzle heaters are in operation for the total length of the mission.
RHEB-208	INV PHASE LOCK  OFF	Central timing signal to inverters supplied through inverter phase synchronizer to provide in-phase a-c power to a-c bus 1 and 2 when a separate inverter is powering each a-c bus.  Provides central timing signal directly to inverters.	None	A-C ØB of inverter 1, 2, or 3	None	Normal position during flight (PSU draws power with control switch in either position).  Position if phase synchronizer unit fails.
LHFEB-300, -301, -302	Suit flow control valve  OFF	Closes valve, shutting off flow of oxygen to suit connector.	N/A	N/A	None	There are three suit connector assemblies in the cabin. Although they vary slightly in appearance, their function is identical, thus suit flow control valve data is covered once. The three suit connector assemblies are located at LHFEB-300, -301, and -302, and are controlled by sliding levers.  Suit hose may be connected or disconnected only with the valve in the OFF position.  The number of suit flow control valves placed to either the CABIN FLOW or the SUIT FULL FLOW positions should always equal the number of crewmen in the C/M.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHFEB-300, -301, -302	CONTROL LEVER RELEASE	Permits free movement of valve control lever by releasing lever locking mechanism.	N/A	N/A	None	When release pushbutton is pressed, locking detent is removed from notch.  The release pushbutton must be pressed to permit movement of the control lever in and out of the OFF position. This prevents inadvertent valve movement out of the closed position when suit hose is disconnected, and into the closed position when the suit hose is connected.
LHFEB-303	CABIN TEMP valve  H (heat)	Manual backup mode position of cabin temperature control valve to increase cabin temperature.	N/A	N/A	None	Motor-operated valve is manually controlled by integral knob. Rotational movement from H to C is approximately 1/2 turn.  Backup mode control knob is used in event of malfunction of cabin temperature control components. This is a dual valve on a single shaft permitting water-glycol flow to heat exchanger to be regulated. Rotation toward the H (heat) position results in proportional increase in cabin temperature by directing warm water-glycol to cabin heat exchanger. There is a definite time lag in cabin temperature response following a manual adjustment; therefore, close coordination between manual adjustments and the TEMP-CABIN indicator (MDC-13) is not necessary.
	C (cool)	Manual backup mode position of cabin temperature control valve to decrease cabin temperature.				Rotation towards the C (cool) position results in proportional decrease in cabin temperature by directing cool water-glycol to cabin heat exchanger. There is a definite time lag in cabin temperature response following a manual adjustment; therefore, close coordination between manual adjustments and the TEMP-CABIN indicator (MDC-13) is not necessary.
	Cabin air control louver	Manually operated louver for adjusting direction of airflow from cabin air fans.				

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHFEB-304	DRINKING WATER SUPPLY shutoff valve  ON  OFF	Permits flow of potable water to water delivery unit.  Turns off flow of potable water to water delivery unit.	N/A	N/A	None	Shutoff valve manually controlled by T-handle tool.  Normal position of valve is on.  Valve is closed in event of leak in water delivery unit.
LHFEB-305	FOOD PREPARATION WATER supply unit  COLD valve  HOT valve	Upon actuation, permits metered amount of cold water (50°F) to food reconstitution nozzle.  Upon activation, permits metered amount of hot water (154±4°F) to food reconstitution nozzle.	N/A	N/A	None	Cold or hot water is metered at a rate of 1.00±0.05 ounce per valve actuation. Upon release, valves return to closed position.
LHFEB-306	GMT clock  TO EVENT and FROM EVENT timers	Mission elapsed time indicator.  Provides crew with a means of monitoring and timing events.	N/A	N/A	None	This clock has a 24-hour dial face with standard second, minutes, and hour hands. A time-set screw, at the bottom left of the dial face, is used to synchronize the clock with Greenwich mean time.  Each timer has a 10-hour dial face with second, minute, hour and 10-hour hands. A knob at the bottom left of each timer is used to set the timer hands. Each timer can be reset, started, or stopped by a push-control at the top right of the timer.
LHFEB-318	SCIENTIFIC EQUIPMENT receptacle switch  ON  OFF	Applies d-c power from nonessential bus No. 2 to SCIENTIFIC EQUIPMENT receptacle for COAS and 16 mm sequence camera.  Removes d-c power from SCIENTIFIC EQUIPMENT receptacle.	SCIEN EQUIP. HATCH (MDC-22)	+28 vdc	None	

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-307	CABIN PRESSURE RELIEF valves		N/A	N/A	None	There are two cabin pressure-relief valves that normally operate automatically to provide positive and negative cabin pressure relief. The upper manual control (three valve positions) and the lower manual control (four valve positions) can override their corresponding relief valves to the CLOSE and NORMAL positions, while only the lower manual control can override its corresponding relief valve to the DUMP position. Horizontal pressure must be applied to move controls out of detent.
	CLOSE	Manual override position to close either cabin pressure-relief valve.				Both relief valves are closed for prelaunch checkout and during C/M RCS propellant dump, while either one or both relief valves are closed in flight in event of valve malfunction.
	NORMAL	Manual override position to partially restrict travel of either cabin pressure-relief valve in the automatic mode.				Normal position of controls for flight period between ascent and entry. Valves are limited to the partially open position to prevent rapid cabin decompression in event valves fail open.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-307 (Cont)	BOOST ENTRY	Neutral position of override mechanism to permit both cabin pressure-relief valves full travel in the automatic mode.	N/A	N/A	None	Except for time required to dump RCS propellants during descent, both controls are normally set to the BOOST ENTRY position for the ascent and entry phases.
	DUMP	Manual override position of lower control to open corresponding cabin pressure-relief valve.				Valve is opened to intentionally vent cabin to outside atmosphere in event of contamination or fire. Mechanical safety latch must be off to set lever in dump position.
	GLYCOL TO RAD valve					Shutoff valve is manually controlled by T-handle tool.
	OPEN	Permits flow of water-glycol from C/M to space radiators in S/M.				Normal position of valve is OPEN.
	CLOSE	Shuts off flow of water-glycol from C/M to space radiators in S/M.				Valve is closed prior to CSM separation to shut off water-glycol flow to S/M.
	GLYCOL RESERVOIR controls					
	INLET valve					Shutoff valve is manually controlled by T-handle tool.
	OPEN	Permits flow of water-glycol from system into reservoir.				Valve is opened to direct water-glycol flow through reservoir during pre-launch and ascent phases and is operated in conjunction with GLYCOL RESERVOIR OUTLET and GLYCOL RESERVOIR BYPASS valves.
	CLOSE	Shuts off flow of water-glycol from system into reservoir.				Valve is closed upon completion of ascent phase to isolate reservoir from system.
	BYPASS valve					Shutoff valve is manually controlled by T-handle tool.
	OPEN	Opens bypass line permitting flow around water-glycol reservoir.				Valve is opened upon completion of ascent phase to bypass and isolate reservoir from system, and is operated in conjunction with GLYCOL RESERVOIR OUTLET and GLYCOL RESERVOIR INLET valves.
	CLOSE	Closes bypass line that permits flow around water-glycol reservoir.				Valve is closed to direct water-glycol flow through reservoir during pre-launch and ascent phases.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-307 (Cont)	OUTLET valve	Permits flow of water-glycol from outlet of reservoir into system.	N/A	N/A	None	Shutoff valve is manually controlled by T-handle tool.
	OPEN					Valve is opened to direct water-glycol flow through reservoir during prelaunch and ascent phases, and is operated in conjunction with GLYCOL RESERVOIR INLET and GLYCOL RESERVOIR BYPASS valves.
	CLOSE	Shuts off flow of water-glycol from outlet of reservoir into system.				Valve is closed upon completion of ascent phase to isolate reservoir from system.
	OXYGEN controls					
	ENTRY valve					
	ON	Permits flow from 1-lb entry oxygen tank into C/M oxygen supply subsystem.				Shutoff valve is manually controlled by T-handle tool.
	OFF	Shuts off flow between 1-lb entry tank and C/M oxygen supply subsystem.				Valve furnishes 1 lb of oxygen as a redundant supply to the normal surge tank quantity of 3.7 lb.
	FILL	Permits flow from C/M oxygen supply subsystem to bypass the check valve and thus fill the 1-lb entry tank.				Tank filled to approximately 900 psig at a rate of 0.66 pounds/minute.
	S/M SUPPLY valve					
	ON	Permits flow of oxygen to C/M from supply in S/M.				Shutoff valve is manually controlled by T-handle tool.
	OFF	Shuts off flow of oxygen to C/M from supply in S/M.				Normal position of valve is ON.
	SURGE TANK valve					
	ON	Permits flow of oxygen to and from surge tank.				Valve is closed prior to CSM separation to prevent C/M entry oxygen supply from flowing overboard in event of check valve failure.
						Shutoff valve is manually controlled by T-handle tool.
						Normal position of valve is ON, permitting surge tank to carry out function of supplying additional oxygen

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-307 (Cont)	OFF	Shuts off flow of oxygen to and from surge tank.	N/A	N/A	None	beyond the normal maximum flow capability from the S/M. and for entry.  Set O <sub>2</sub> PRESS IND switch (MDC-13) to SURGE TANK to obtain indication.  Valve is closed to preserve surge tank supply in event cryogenic oxygen tank pressure drops to 900 psig or below.
LHEB-308	SURGE TANK PRESSURE RELIEF shutoff valve  OPEN (cs)  Close (ccw)	Opens line from surge tank to relief valve permitting relief function.  Closes line from surge tank to relief valve eliminating relief function.	N/A	N/A	None	Shutoff valve is manually controlled by T-handle tool. Rotational movement from OPEN to close is 1/4 turn.  OPEN position enables relief valve to function when surge tank pressure increases to 1045±25 psig.  Valve is closed only if surge tank relief valve fails open.
LHEB-309	GLYCOL PRESS RELIEF BYPASS valves  Valve 1  ON  OFF  Valve 2  ON  OFF	Permits flow of water-glycol to No. 1 water-glycol pressure-relief valve.  Shuts off flow of water-glycol to No. 1 water-glycol pressure-relief valve.  Permits flow of water-glycol to No. 2 water-glycol pressure-relief valve.  Shuts off flow of water-glycol to No. 2 water-glycol pressure-relief valve.	N/A	N/A	None	Except for ascent and entry, one pressure-relief valve is selected for use at a time, with the second valve for standby redundancy.  Shutoff valve is manually controlled by T-handle tool.  Normal position of valve No. 1 when valve No. 2 is OFF.  Normal position of valve No. 1 when valve No. 2 is ON, or in event of malfunction of No. 1 pressure-relief valve:  Shutoff valve is manually controlled by T-handle tool.  Normal position of valve No. 2 when valve No. 1 is OFF.  Normal position of valve No. 2 when valve No. 1 is ON, or in event of malfunction of No. 2 pressure relief valve.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-310	O <sub>2</sub> DEMAND REGULATOR		N/A	N/A	None	Valve is manually controlled by T-handle tool.
	1	Directs regulated oxygen (100±10 psig) to No. 1 suit demand pressure regulator.				Valve set to position 1 in event of malfunction of No. 2 demand pressure regulator.
	1 & 2	Directs regulated oxygen (100±10 psig) to No. 1 and No. 2 suit demand pressure regulators.				Both demand pressure regulators are selected for simultaneous use under normal conditions for redundancy in event of one regulator malfunctioning.
	2	Directs regulated oxygen (100±10 psig) to No. 2 suit demand pressure regulator.				Valve set to position 2 in event of malfunction of No. 1 demand pressure regulator.
	OFF	Shuts off regulated oxygen (100±10 psig) to No. 1 and No. 2 suit demand pressure regulators.				Valve set to OFF position only if both suit demand pressure regulators malfunction.
	SUIT TEST valve					Valve is operated by an integral lever.
	PRESS	Routes regulated oxygen flow (100±10 psig) directly into suit circuit through a pressurization orifice at a maximum buildup rate of 4 psig per minute for PGA/suit circuit tests.				With valve in PRESS position, suit circuit will increase 4.25 psia above the nominal pressure of 5.0±0.3 psia. Approximately 75 seconds must be allowed for suit circuit pressure to reach maximum. This test may be performed at ground checkout or during flight.
	DEPRESS	Shuts off O <sub>2</sub> flow to suit circuit upon completion of test, permitting reduction of pressure buildup at an average bleedoff rate of 4 psig per minute.				Approximately 75 seconds must be allowed for the increased suit circuit pressure to bleed back to the nominal 5.0±0.3 psia.
	OFF	Permits normal O <sub>2</sub> flow to suit circuit through suit demand pressure regulator.				Normal position of valve when not conducting a PGA/suit circuit test. Valve must not be set to off position before suit circuit has returned to nominal pressure.
	SUIT HT EXCH switch					Regardless of switch position, the SUIT EVAP switch (MDC-13) must be in AUTO position for automatic control of suit circuit temperature.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-310 (Cont)	GLY/EVAP  EVAP	Places suit circuit temperature control complex in full automatic mode, whereby, cooling is accomplished either by water-glycol or water evaporation.  Overrides full automatic mode of suit heat exchanger temperature control complex by positioning the water-glycol diverter valve in the bypass position, thereby, initiating the automatically controlled water evaporation cooling mode.	N/A	N/A	None	In the GLY/EVAP position, the switch is open. This prevents shorting across the circuit of the suit heat exchanger air outlet temperature sensor, and permits the sensor to automatically activate the water evaporation mode if the temperature reaches 60°F or more.  In the EVAP position, the switch is closed. This shorts across the circuit of the suit exchanger air outlet temperature sensor, and creates the same effect as an overtemp condition (above 60°F) on this sensor.  This switch position is selected for cabin cold-soak operation, or if suit temperature control complex malfunctions.
LHEB-311	SUIT EVAP GLYCOL valve  ON  OFF	Manual override position of water-glycol diverter valve, routing coolant flow to the suit heat exchanger for suit circuit cooling.  Manual override position of water-glycol diverter valve, bypassing coolant flow around suit heat exchanger and activating water evaporation cooling mode.	N/A	N/A	None	Motor-operated valve is manually controlled by T-handle tool.  Normal position of valve is ON to permit the automatic suit temperature control complex to select the water-glycol or water evaporation cooling mode.  Valve is set to OFF position for backup cabin cold-soak operation or in event of suit temperature control malfunction. Movement of diverter valve mechanically operates switch that activates water evaporation cooling mode.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-311 (Cont)	SUIT FLOW RELIEF valve		N/A	N/A	None	Valve is manually controlled by T-handle tool.
	AUTO	Removes override lever from poppet valve, permitting automatic pressure-relief action to take place at a $\Delta P$ of 5 (+0.6, -0.2) inches $H_2O$ .				Normal position of valve is AUTO to maintain constant suit flow in event of suit circuit flow resistance fluctuations.
	OFF	Applies override lever to poppet valve holding valve in closed position.				Valve is manually closed in event of its failure to close when in the automatic mode.
	GLYCOL EVAP TEMP IN valve					Motor-operated valve is manually controlled by T-handle tool. Rotational movement from HEAT to cool is just over 1/4 turn.
	HEAT (ccw)	Manual backup mode position of water-glycol temperature control valve to increase temperature of water-glycol entering evaporator.				Backup mode is used in event of malfunction of water-glycol temperature control components. Rotation toward the HEAT position results in a proportional temperature increase by changing the mixture ratio of hot-to-cold water-glycol. Close coordination between valve adjustments and GLY EVAP - OUTLET TEMP indicator (MDC-13) is necessary to obtain correct water-glycol temperature.
	Cool (ccw)	Manual backup mode position of water-glycol temperature control valve to decrease temperature of water-glycol entering evaporator.				Rotation toward the cool position results in a proportional temperature decrease by changing the mixture ratio of cold-to-hot water-glycol. Close coordination between valve adjustments and GLY EVAP - OUTLET TEMP indicator is necessary to obtain correct water-glycol temperature.
	$H_2O$ ACCUMULATOR selector valves					Valves manually controlled by T-handle tool.
	Valve 1					
	MAN	Routes regulated oxygen (100±10 psig) to No. 1 cyclic accumulator, bypassing solenoid shutoff valve.				Valve position is selected only when No. 2 accumulator has failed and No. 1 solenoid shutoff valve cannot be operated automatically or by

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-311 (Cont)	OFF	Shuts off regulated oxygen (100±10 psig) to solenoid shutoff valve and bypass line to No. 1 cyclic accumulator.	N/A	N/A	None	manually selected electrical impulse. Valve will then be positioned to MAN for approximately 10 seconds every 30 minutes.
	RMTE	Routes regulated oxygen (100±10 psig) to solenoid shutoff valve of No. 1 cyclic accumulator.				Normal position of valve is RMTE, permitting automatic (CTE) or manually selected electrical impulse to operate solenoid shutoff valve. Manually selected electrical operation is used in event of automatic control unit malfunction.
	Valve 2					Valve manually controlled by T-handle tool.
	MAN	Routes regulated oxygen (100±10 psig) to No. 2 cyclic accumulator, bypassing solenoid shutoff valve.				Valve position is selected only when No. 1 accumulator has failed and No. 2 solenoid shutoff valve cannot be operated automatically or by manually selected electrical impulse. Valve will be positioned to MAN for approximately 10 seconds every 30 minutes.
	OFF	Shuts off regulated oxygen (100±10 psig) to solenoid shutoff valve and bypass line to No. 2 cyclic accumulator.				
	RMTE	Routes regulated oxygen (100±10 psig) to solenoid shutoff valve of No. 2 cyclic accumulator.				Normal position of valve is RMTE permitting automatic CTE or manually selected electrical impulse to operate solenoid shutoff valve. Manually selected electrical operation is used in event of automatic control unit malfunction.
	GLYCOL RESERVE valve					Shutoff valve is manually controlled by T-handle tool.
	ON	Permits flow of water-glycol from reservoir into system.				Valve is opened to refill water-glycol system following the discovery and isolation of a leak.

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Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-311 (Cont)	OFF	Shuts off flow of water-glycol from reservoir into system.	N/A	N/A	None	Normal position of valve is OFF to isolate water-glycol reservoir from system.
	EVAP H <sub>2</sub> O valve					Valve is manually controlled by T-handle tool.
	AUTO	Permits water flow to water-glycol evaporator solenoid-operated water inflow control valve.				Normal position of valve.
	OFF	Shuts off water flow to water-glycol evaporator water inflow control valve.				Valve is manually closed to prevent flooding water-glycol evaporator in event solenoid valve fails open.
	SUIT EVAP selector valve					Valve is manually controlled by T-handle tool.
LHEB-312	AUTO	Routes flow of water to solenoid-operated water inflow control valve for suit circuit evaporative cooling.				Valve set to AUTO position during all automatic suit temperature control operations.
	OFF	Shuts off flow of water to water inflow control valve and bypass line to suit evaporator.				Valve set to OFF position in event water inflow control valve fails open.
	MAN	Bypasses flow of water around water inflow control valve, routing it directly into the suit evaporator.				Valve set to MAN position for manual backup mode of evaporative cooling. This method is effective only if the steam-pressure control valve is in any position other than close. A malfunction in the temperature control components could leave the steam pressure control valve in any position.
	GLYCOL ACCUMULATOR shutoff valve					Shutoff valve is manually controlled by torque wrench and 10-inch driver.
	On (ccw)	Permits flow of water-glycol from system to and from water-glycol accumulator.	N/A	N/A	None	Normal position of valve is on, permitting accumulator to carry out function of damping surges and oscillations, and maintaining pump inlet pressure.
	OFF (cw)	Shuts off flow of water-glycol from system to water-glycol accumulator.				Valve is closed to isolate a leaking accumulator from water-glycol system.

LH EQUIPMENT BAY—PANELS 311 AND 312

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APOLLO OPERATIONS HANDBOOK

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-313	CO <sub>2</sub> -odor absorber diverter valve  UP  Center  Down	Shuts off suit circuit flow to canister B and diverts the full flow to canister A.  Neutral position of valve permitting equal suit circuit flow to each canister.  Shuts off suit circuit flow to canister A and diverts the full flow to canister B.	N/A	N/A	None	The diverter valve linkage includes a mechanical interlock that assures cover removal of only the canister that has been isolated from the suit flow.
LHEB-314	MAIN REGULATOR selector valve  NORMAL  1  OFF  2	Directs supply of oxygen from S/M to No. 1 and No. 2 main pressure regulator and relief valves.  Directs supply of oxygen from S/M to No. 1 main pressure regulator and relief valve.  Shuts off supply of oxygen from S/M to No. 1 and No. 2 main pressure regulator and relief valves.  Directs supply of oxygen from S/M to No. 2 main regulator and relief valve.	N/A	N/A	None	Selector valve is manually controlled by integral knob.  Regulators No. 1 and No. 2 are selected for simultaneous use under normal conditions.  Valve set to position 1 in event of malfunction of No. 2 main pressure regulator and relief valve.  Valve set to position 2 in event of malfunction of No. 1 main pressure regulator and relief valve.
	WATER & GLYCOL TANKS PRESSURE controls  REGULATOR-SELECTOR INLET valve  NORMAL	Directs regulated oxygen (100±10 psig) to No. 1 and No. 2 tank pressure regulators for reduction to 20±-psig tank pressure.				Selector valve is manually controlled by T-handle tool.  Both tank pressure regulators are selected for simultaneous use under normal conditions for redundancy in event of one regulator malfunctioning.  <b>Caution</b> If the SELECTOR INLET valve is placed to position 1 or 2, the SELECTOR OUTLET valve must be placed to the corresponding position (or NORMAL) to prevent shutting off supply of oxygen for pressurizing the water tanks and water-glycol reservoir.

LH EQUIPMENT BAY—PANELS 313 AND 314

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APOLLO OPERATIONS HANDBOOK

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-314 (Cont)	1	Directs regulated oxygen (100±10 psig) to No. 1 tank pressure regulator for reduction to 20±2-psig tank pressure.	N/A	N/A	None	Valve is set to position 1 in event of malfunction of No. 2 tank pressure regulator.
	OFF	Shuts off regulated oxygen (100±10 psig) to No. 1 and No. 2 tank pressure regulators.				With valve in OFF position, tank pressurization system is isolated from regulated oxygen supply.
	2	Directs regulated oxygen (100±10 psig) to No. 2 tank pressure regulator for reduction to 20±2-psig tank pressure.				Valve is set to position 2 in event of malfunction of No. 1 tank pressure regulator.
	RELIEF-SELECTOR OUTLET valve NORMAL	Directs oxygen pressure from potable and waste water tanks to No. 1 and No. 2 tank pressure regulator relief valves.				Selector valve is manually controlled by T-handle tool.  Both tank pressure-relief valves are selected for simultaneous use under normal conditions for redundancy in event of one relief valve malfunctioning.  There is no meter to indicate pressurization of potable and waste water tanks and glycol reservoir.  <b>Caution</b> If the SELECTOR OUTLET valve is placed to position 1 or 2, the SELECTOR INLET valve must be placed to the corresponding position (or NORMAL) to prevent shutting off supply of oxygen for pressurizing the water tanks and water-glycol reservoir.  Valves set to position 1 in event of malfunction of No. 2 tank pressure regulator relief valve.  With valve in OFF position, any increase in oxygen pressure is trapped and cannot be relieved.
	1	Directs oxygen pressure from potable and waste water tanks to No. 1 tank pressure regulator relief valve.				
	OFF	Shuts off oxygen pressure from potable and waste water tanks to No. 1 and No. 2 tank pressure regulator relief valves.				
	2	Directs oxygen pressure from potable and waste water tanks to No. 2 tank pressure regulator relief valve.				Valve set to position 2 in event of malfunction of No. 1 tank pressure regulator relief valve.
	PLSS FILL valve	Manual shutoff valve controlling filling of PLSS tank with oxygen from supply in surge tank.				Valve is manually controlled by integral T-handle. Rotational movement from open to CLOSE is approximately 2 turns.

LH EQUIPMENT BAY—PANEL 314

## APOLLO OPERATIONS HANDBOOK

## CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-314 (Cont)			N/A	N/A	None	Normal position of valve is closed. Valve is opened when used in conjunction with adjacent PLSS FILL connector.
	EMERGENCY CABIN PRESSURE selector valve					Selector valve is manually controlled by T-handle tool.
	NORMAL	Directs regulated oxygen (100±10 psig) to No. 1 and No. 2 emergency cabin pressure regulators.				Both emergency regulators are selected for simultaneous use under normal conditions, for redundancy in event of emergency decompression as a result of cabin wall puncture.
	1	Directs regulated oxygen (100±10 psig) to No. 1 emergency cabin pressure regulator.				Valve set to position 1 in event of malfunction of No. 2 emergency regulator.
	OFF	Shuts off regulated oxygen (100±10 psig) to No. 1 and No. 2 emergency cabin pressure regulators				Valve is set to OFF position whenever all crewmen are suited. With valve in OFF position, both emergency regulators are isolated from regulated oxygen supply.
	2	Directs regulated oxygen (100±10 psig) to No. 2 emergency cabin pressure regulator.				Valve set to position 2 in event of malfunction of No. 1 emergency regulator.
	PRESS TO TEST pushbutton	Permits No. 1 and No. 2 emergency cabin pressure regulators to be simultaneously tested for operational verification.				With pushbutton pressed, vents to reference pressure chambers of both regulators are closed off. This allows an artificial reference pressure to build up which results in regulator operation. This test may be accomplished at ground checkout or during flight.
	CABIN REPRESS manual valve					Shutoff valve is manually controlled by integral knob. Rotational movement from OPEN to close is approximately 3/4 turn.
	OPEN (cw)	Directs oxygen into cabin up to the maximum flow rate of 7.2 lb per hr. Poppet-type valve is an independent unit of the cabin pressure regulator assembly.				Both normal cabin pressure regulators are in use simultaneously and cannot be selected or turned off. In the event both regulators fail in the closed or fail-safe position, the manual shutoff valve is used to maintain cabin pressure. Valve is also used to repressurize cabin after decompression.
	Close (ccw)	Shuts off oxygen flow into cabin.				

LH EQUIPMENT BAY—PANEL 314

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CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
I.H.E.B-314 (Cont)	TOOL STORAGE receptacle	Flush-mounted receptacle for storing universal T-handle tool used in positioning numerous manually operated valves.	N/A	N/A	None	A second T-handle tool is stowed in socket of suit circuit DIRECT O <sub>2</sub> metering valve (MDC-24) for use in positioning those valves accessible to crewman in LH couch.
I.H.E.B-315	WASTE TANK SERVICING OPEN CLOSE	Permits flow of water into waste water tank from ground servicing connection. Shuts off flow of water into waste water tank from ground servicing condition.	N/A	N/A	None	Shutoff valve is manually controlled by T-handle tool. Valve is opened when used in conjunction with adjacent WASTE TANK SERVICING connector.
	PRESSURE RELIEF selector valve BOTH 1 OFF 2	Directs flow of excess potable or waste water to No. 1 and No. 2 pressure relief valves. Directs flow of excess potable or waste water to No. 1 pressure relief valve. Shutoff flow of excess potable and waste water to No. 1 and No. 2 pressure relief valves. Directs flow of excess potable and waste water to No. 2 pressure relief valve.				Selector valve is manually controlled by integral lever. Both pressure relief valves are selected for simultaneous use under normal conditions, for redundancy in event of one relief valve malfunctioning. Valve set to position 1 in event No. 2 pressure relief valve malfunctions. With valve in OFF position, excess water cannot be dumped overboard. Unless both relief valves fail to open, this valve position is used for ground checkout only. Valve set to position 2 in event No. 1 pressure relief valve malfunctions.
	POTABLE TANK INLET valve OPEN CLOSE	Permits flow of water from fuel cells into potable water tank. Shuts off flow of water from fuel cells into potable water tank.				Shutoff valve is manually controlled by T-handle tool. Normal position of valve is OPEN. Valve set to CLOSE position to isolate potable water tank in event water from fuel cells becomes contaminated.

LH EQUIPMENT BAY—PANELS 314 AND 315



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APOLLO OPERATIONS HANDBOOK

CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
LHEB-315 (Cont)	WASTE TANK INLET valve  AUTO  CLOSE	Permits flow of water from fuel cells into waste water tank when relief valve differential pressure reaches 6.0±0.5 psi.  Shuts off flow of water from fuel cells to differential pressure-relief valve and waste water tank.	N/A	N/A	None	Shutoff function of this relief-shutoff valve is manually controlled by T-handle tool.  Normal position of valve is AUTO. If potable water tank is full or waste tank is empty, water from fuel cells will flow into waste water tank when relief valve reaches 6.0±0.5 psid.  Valve set to CLOSE position in event relief valve fails open, prematurely permitting potable water flow into waste water tank.
LHEB-316	PLVC switch  NORMAL  OPEN	Applies d-c power to pendulum-type attitude sensing switch of PLV system during normal post-landing operations.  Applies d-c power directly to PLV valves, placing valves in open position in event of abnormal postlanding operations.	POSTLAND-ING VENT-FAN - PL BUS/FLOAT BAG 2 (MDC-25)	Flight and Postlanding Bus	None	Switch set to NORMAL position to permit normal operation of attitude sensing switch (to close PLV valves) when C/M becomes inverted or tilts beyond a specified limit.  Switch set to OPEN position in event of attitude sensing switch failure, or to aid crew to escape from inverted C/M.
LHEB-317	GLY EVAP WATER CONTROL BYPASS valve  ON  OFF	Permits flow of water directly into water-glycol evaporator by bypassing solenoid-operated water inflow control valve.  Shuts off flow of water bypassing water-glycol evaporator inflow control valve.	N/A	N/A	None	LHEB-317 consists of two components. A manually operated water control valve installed in the LHEB, and a plug-in unit to measure glycol evaporator-wick temperature stowed in the C/M cabin. Data on plug-in unit TBD.  Valve set to ON position in event of water-glycol evaporator temperature control failure.  Normal position of valve is OFF.
LHEB-319	SUIT CIRCUIT RETURN SHUT-OFF VALVE  O (open)  C (closed)	Permits flow of cabin gases to enter suit circuit for processing.  Shuts off flow of cabin gases entering suit circuit.	N/A	N/A	None	Shutoff valve is manually controlled by knurled knob.  Normal position of valve is open.  Valve is closed during ascent and descent, as access to valve is blocked. Valve is also closed to isolate suit circuit in event of cabin contamination.

LH EQUIPMENT BAY—PANELS 315, 316, 317, AND 319

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CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
Left Armrest LH Couch	Translation controls  Neutral position  In/out  Left/right  Up/down	<p>Actuates all switches located within the control to the open position.</p> <p>Applies +X or -X translation command signal to SCS electronics.</p> <p>Applies +Y or -Y translation command signal to SCS electronics.</p> <p>Applies +Z or -Z translation command signal to SCS electronics.</p>	SCS- GROUP 1 MN A MN B (MDC-25)	D-C main bus A or B	None	<p>Two nearly identical translation controls are installed in the S/C. The functions are identical with one exception: the CCW switch function is not available from the No. 2 control. S/C translations are accomplished by use of S/M RCS only. Physically, the No. 1 control is identified by the presence of yellow diagonal striping on the top and right hand side.</p> <p>A push-to-talk mike switch is located on the control handle. When pressed, the switch enables audio transmission capability in certain modes of communication system operation.</p> <p>The electrical cabling plugs, for the two translation controls, are connected at the LHEB.</p>

LEFT ARMREST, LH COUCH

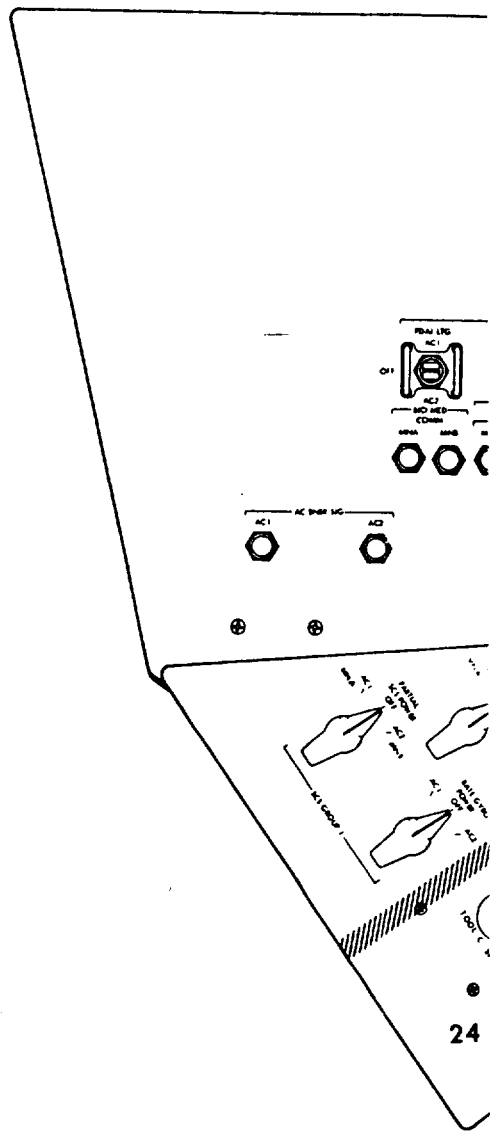
## APOLLO OPERATIONS HANDBOOK

## CONTROLS AND DISPLAYS

Location	Name and Position	Function	Circuit Breaker	Power Source	Telemetry Code No. and Identity	Remarks
Left Armrest LH Couch (Cont)	CCW (rotation)	a. Initiates manual abort command signal to the MESG. b. Provides a backup for CSM/booster separation after all stages are expended.	MASTER EVENT SEQ CONT — A LOGIC B BAT A BAT B (MDC-22)	Battery buses A and B	None	The translation control must be in the neutral position prior to engaging MESG logic A and B circuit breakers. Failure to confirm neutral positioning could result in an inadvertent abort or separation.  Due to a positive detent the translation control must be manually returned to neutral from the CCW or CW position. This function is used when normal booster separation fails to occur.
	CW (rotation)	a. Engages manual thrust vector control mode during G&N or SCS ΔV. ΔV switch must be in the ΔV position prior to selecting MTVC. b. Disengages automatic attitude control during G&N or SCS attitude hold.	SCS — GROUP 2 MN A MN B (MDC-25)	D-C main bus A or B		This position may be used to place the S/C in free drift, and at the same time provide S/C attitude information on the FDAI depending on mode selected.
Crew Couches	Rotation controls	Provides manual control of C/M - S/M attitude in all axes.	SCS — GROUP 2 AC 1 AC 2 (MDC-25)	A-C bus No. 1 or A-C bus No. 2	None	Two identical rotation controls are installed in the S/C. The function of both controls is identical. The electrical cabling plugs for the two rotation controls are connected at the RH couch junction box.
	Forward/back (movement)	a. Commands S/C rotation in the pitch axis. b. Provides manual control of SPS engine pitch gimbal after MTVC is engaged.	SCS — DIRECT CONT MN A MN B (MDC-25)	D-C main bus A or B		When using a control, S/C rotation can be commanded two ways, either by proportional rate commands or by direct on commands. Proportional rate command is obtained by utilization of the SCS electronics, and is considered the normal method. Direct on commands are available when the DIRECT RCS switch is used in conjunction with the rotation control.
	Left/right (movement) CW/CCW (rotation)	Commands S/C rotation in the roll axis. a. Commands S/C rotation in the yaw axis. b. Provides manual control of SPS engine yaw gimbal after MTVC is engaged.	SCS — GROUP 2 MN A MN B (MDC-25)			
Pressure Garment Assembly	PCA pressure indicator	Indicates oxygen pressure (PSIA) inside pressure garment assembly.	None	None	None	The indicator is located on the left sleeve between wrist and elbow, on top of arm. The indicator range is from 2 to 10 psia.

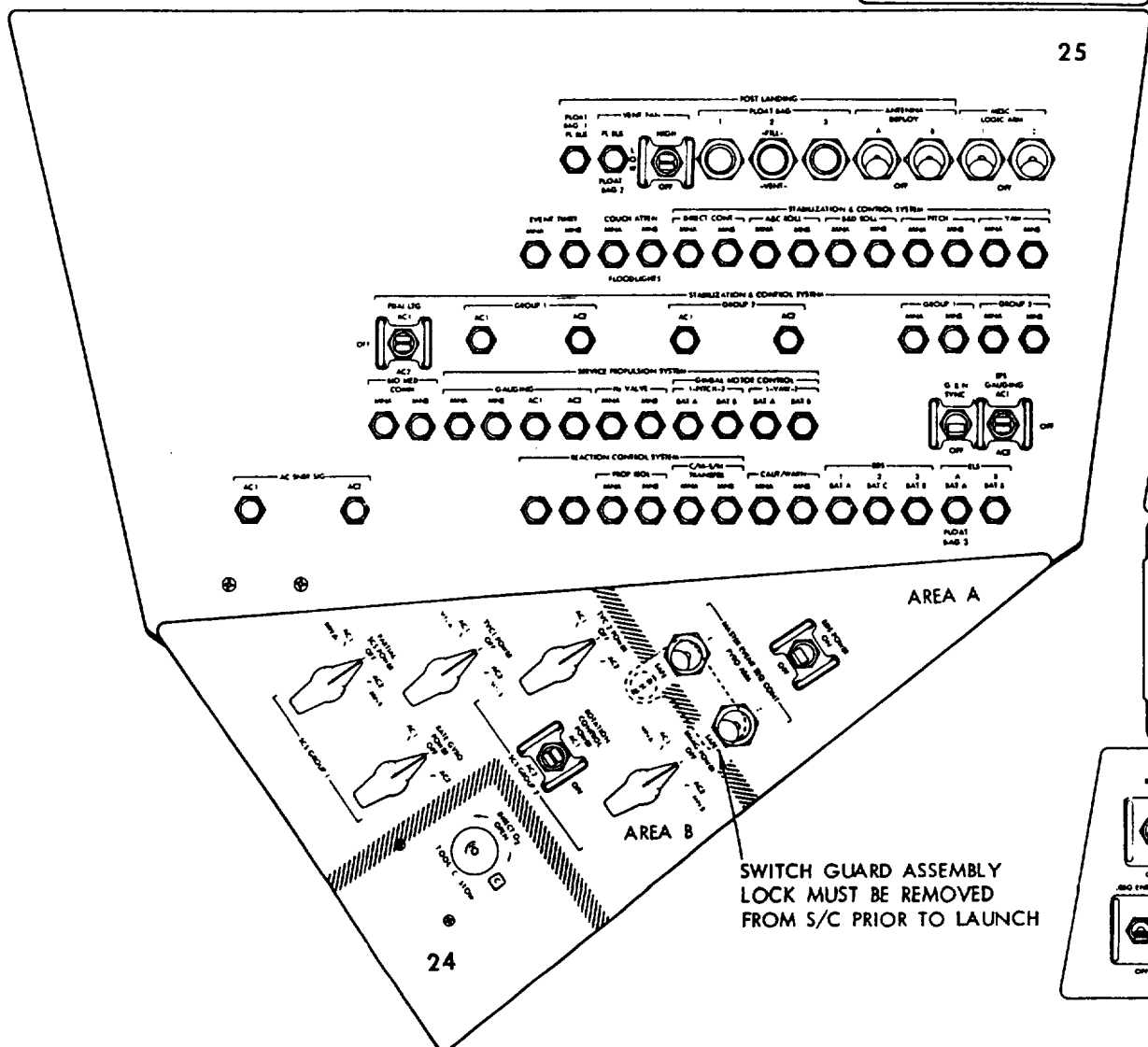
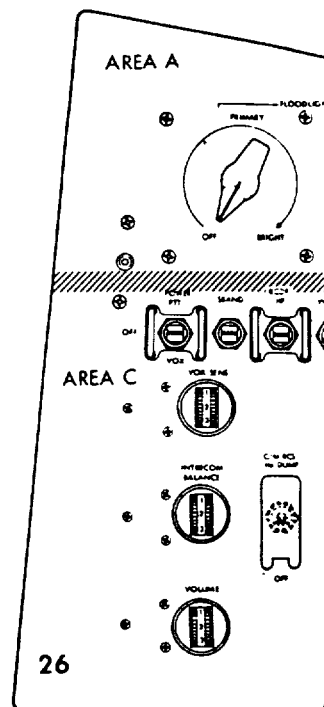
LEFT ARMREST, LH COUCH — CREW COUCHES  
PRESSURE GARMENT ASSEMBLY





FOLDOUT FRAME /





**FOLDOUT FRAME** 2



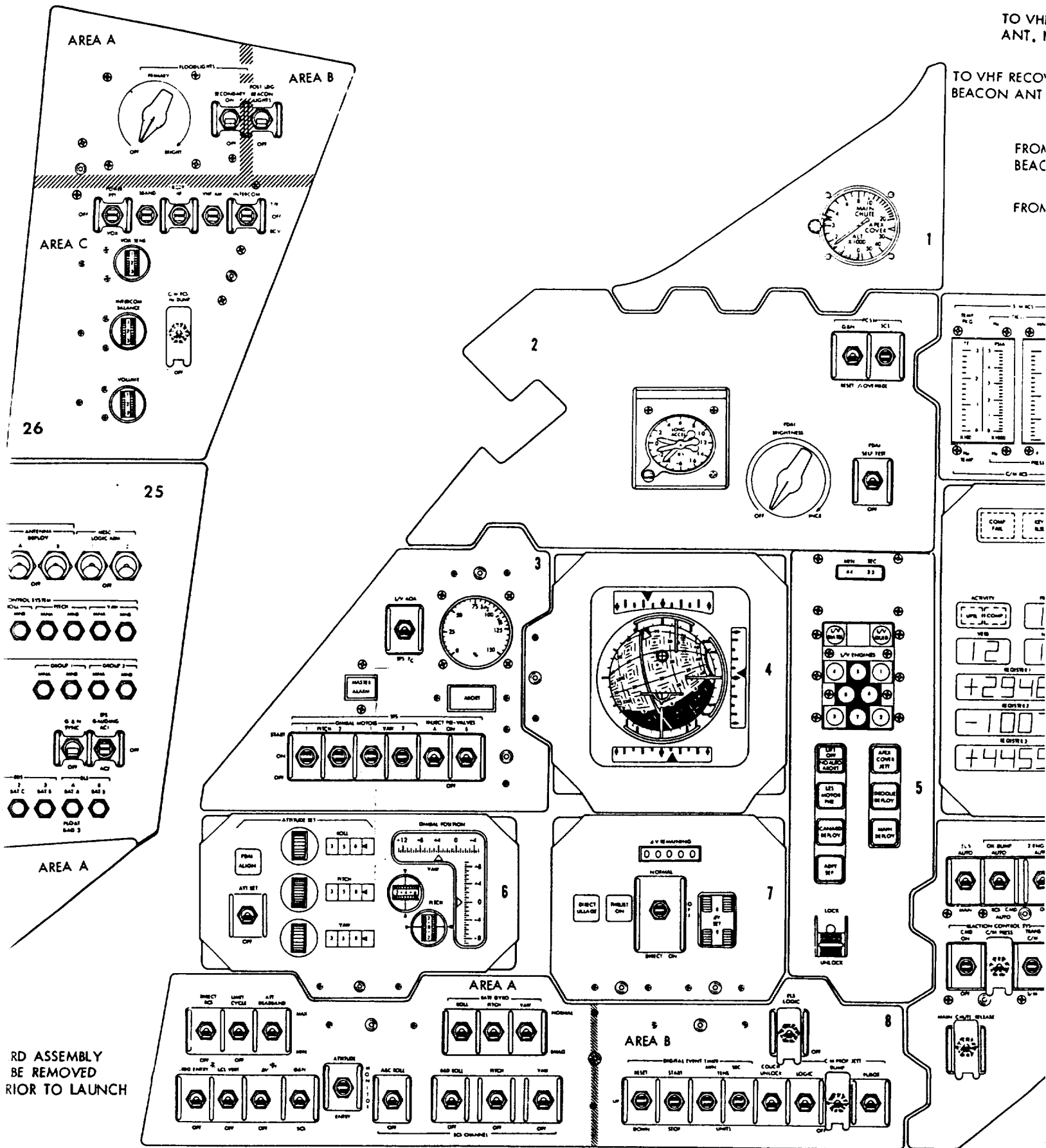


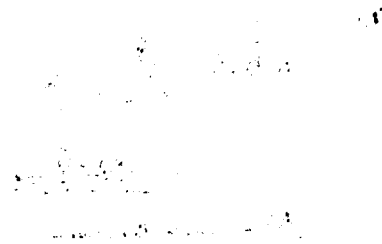
TO VHF  
ANT. 1

TO VHF RECO  
BEACON ANT

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FROM



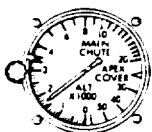


TO VHF/AM RECOVERY  
ANT. NO. 2

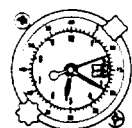
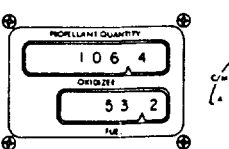
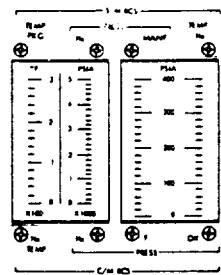
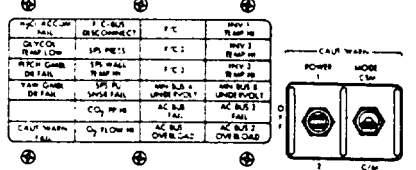
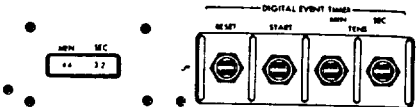
TO VHF RECOVERY  
BEACON ANT NO. 1

FROM VHF RECOVERY  
BEACON

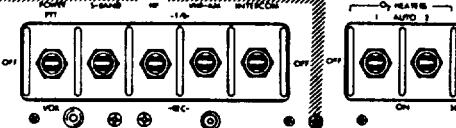
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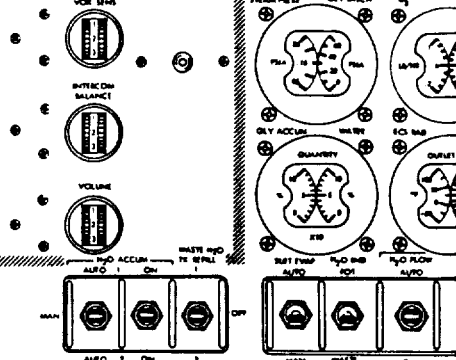
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GEN. ACC. TAIL	GEN. F. RICH	CHAL. L. DEY	W. PRESS
C. W. REC. A	C. W. REC. B	A. C. PRESS	C. W. REC. C
C. W. REC. A	C. W. REC. B	C. W. REC. C	C. W. REC. D
C. W. REC. A	C. W. REC. B	C. W. REC. C	C. W. REC. D
C. W. REC. A	C. W. REC. B	C. W. REC. C	C. W. REC. D
C. W. REC. A	C. W. REC. B	C. W. REC. C	C. W. REC. D
C. W. REC. A	C. W. REC. B	C. W. REC. C	C. W. REC. D



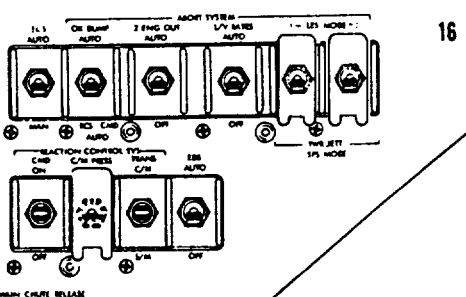
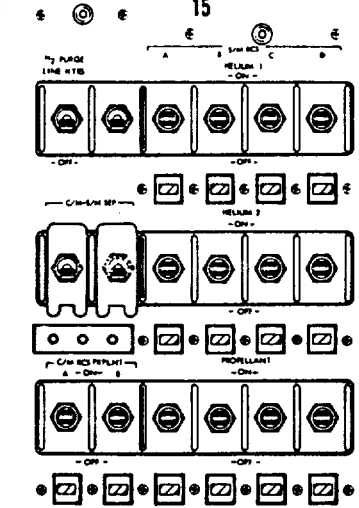
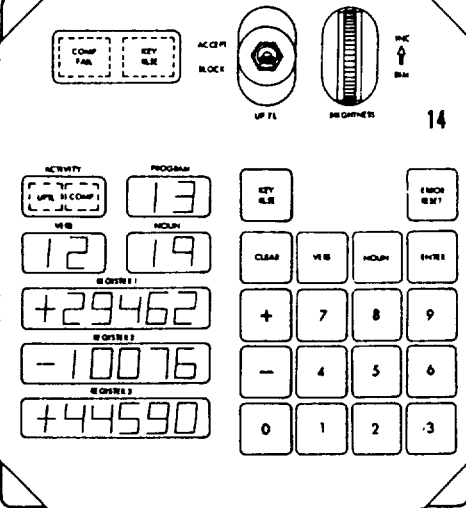
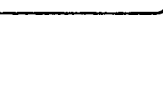
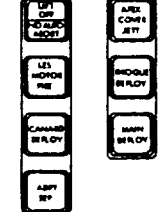
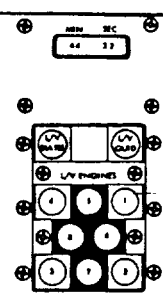
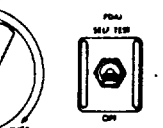
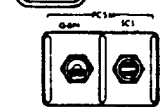
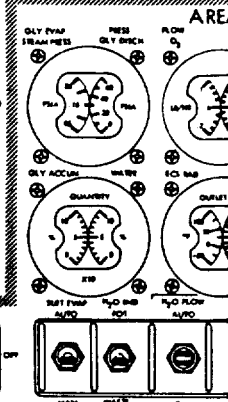
AREA A



AREA B



AREA C

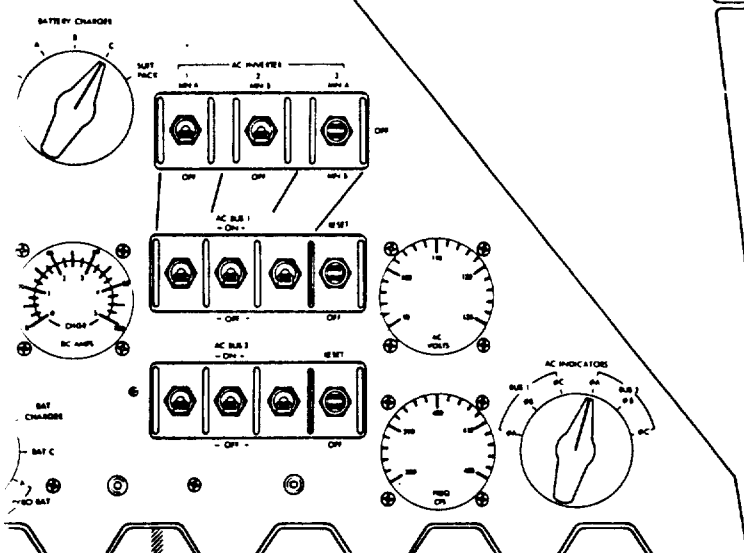
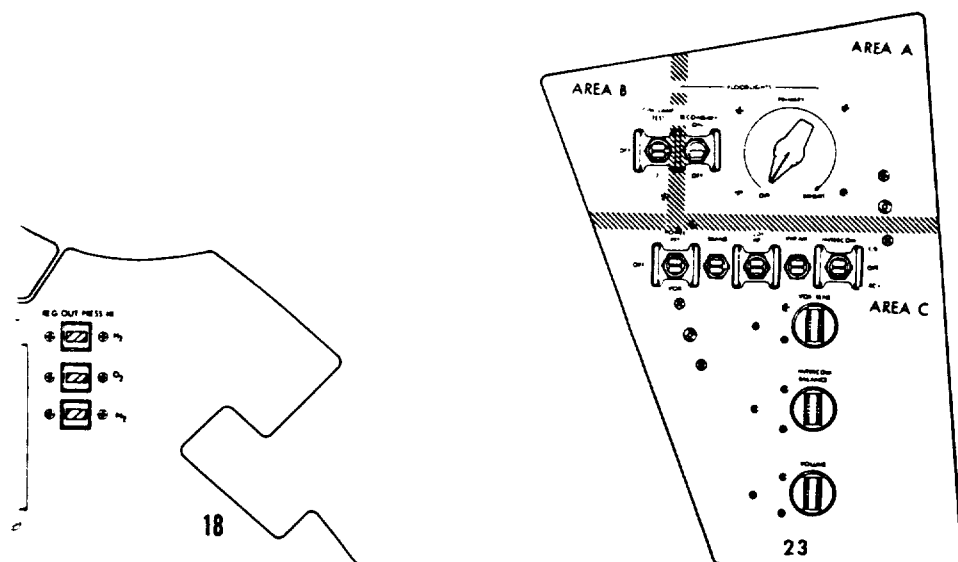


MAIN DISPLAY CONSOLE (MDC)

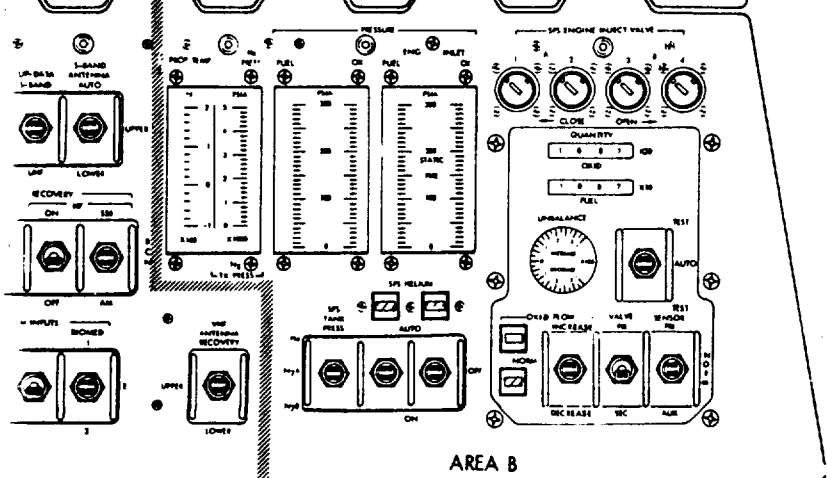
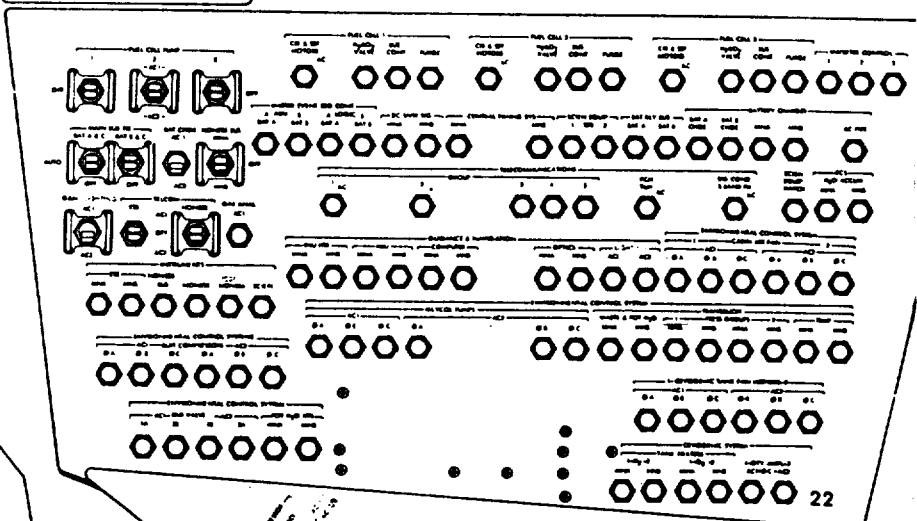








INDEX		
MDC PANEL NO.	CONTROL OR DISPLAY	SY
1	ALTIMETER	SE
2	FDAI	SC
2	LONG ACCEL	ME
2	FCSM group	SP
3	L/V AOA/SPS P <sub>c</sub> sw	SP
3	L/V AOA/SPS P <sub>c</sub> indicator meter	SP
3	ABORT light	SE
3	MASTER ALARM light	CA
3	SPS group	SP
4	FDAI	SC
5	All controls & displays	SC
6	All controls & displays	SE
7	All controls & displays	SC



Mission \_\_\_\_\_

**EXCISE FRAME** 6





CONTROLS AND DISPLAYS

INDEX	
CONTROL OR DISPLAY	SYSTEM
ALTIMETER	SEQ
FDAI	SCS
LONG ACCEL	MISC
CSM group	SPS
1/2 AOA/SPS P <sub>c</sub> sw	SPS, SEQ
1/2 AOA/SPS P <sub>c</sub> indicator meter	SPS, SEQ
ABORT light	SEQ
MASTER ALARM light	C&W
SPS group	SPS
FDAI	SCS
All controls & displays	SEQ
All controls & displays	SCS
All controls & displays	SCS

INDEX				
MDC PANEL NO.	CONTROL OR DISPLAY	SYSTEM		
8	Area A	SCS		
8	Area B - ELS LOGIC, COUCH UNLOCK and DIGITAL EVENT TIMER group	SEQ		
8	Area B - CM PROP JETT group	RCS, SEQ		
9	Coaxial bracket	T/C		
10				
	G&N	G&N	G&N	SCS
	G&N	G&N	G&N	EPS
	RCS	RCS	G&N	EPS
	RCS	RCS	RCS	RCS
	SPS			
11				
	ECS	EPS	EPS	EPS
	ECS	SPS	EPS	EPS
	SPS	SPS	EPS	EPS
	SPS	SPS	EPS	EPS
		ECS	EPS	EPS
	C&W	ECS	EPS	EPS
11	CAUT/WARN group	C&W		
11	DIGITAL EVENT TIMER	SEQ		
12	All controls & displays except MISSION ELAPSED TIME	RCS		
12	MISSION ELAPSED TIME			
12	MISSION ELAPSED TIME			
13	Area A	MISC		
13	Area B	C&W		
13	Area C	T/C		
13	Area D	EPS		
14	All controls & displays	ECS		
15	All controls & displays except C/M-S/M SEP group & H <sub>2</sub> PURGE LINE HTRS	G&N		
15	C/M-S/M SEP group	RCS		
15	H <sub>2</sub> PURGE LINE HTRS	SEQ		
16	ABORT SYSTEM group & ELS AUTO	EPS		
16	MAIN CHUTE RELEASE	SEQ		
16	REACTION CONTROL SYS group	SEQ		
18	All controls & displays except MASTER ALARM LIGHT	RCS		
18	MASTER ALARM LIGHT	EPS		
18	MASTER ALARM LIGHT			
19	F/C VALVES	C&W		
19	S-BAND ANT., UP TLM CMD, FLIGHT QUAL RCDR and VOICE RECORD	EPS		
19	ECS, RAD OUT TEMP	T/C		
20	SPS LINE HTR	ECS		
20	AREA A	SPS		
20	AREA B	T/C		
21	RCS HEATERS group	SM-RCS		
21	SNSR UNIT group	EPS		
21	ECS RADIATOR group	ECS		
21	CABIN AIR FAN group	ECS		
21	POT H <sub>2</sub> O HEATER	ECS		
21	ECS GLYCOL	ECS		
21	SUIT COMPRESSOR	ECS		
22	All controls on top row	EPS		
22	ECS group	ECS		
22	SCIEN EQUIP HATCH	EXP		
22	MAIN BUS TIE group	EPS		
22	BAT CHGR and NONESS BUS	EPS		
22	DC SNSR SIG group	EPS		
22	CENTRAL TIMING SYS group	T/C		
22	SCIEN EQUIP group	EXP		
22	BAT RLY BUS group	EPS		
22	BATTERY CHARGER group	EPS		

INDEX		
MDC PANEL NO.	CONTROL OR DISPLAY	SYSTEM
22	G&N LIGHTING	G&N
22	TELCOM group	T/C
22	TELECOMMUNICATIONS group	T/C
22	MASTER EVENT SEQ CONT group	SEQ
22	GUIDANCE & NAVIGATION group	G&N
22	1 - CRYOGENIC SYS TANK FAN MOTORS - 2	EPS
22	CRYOGENIC SYSTEM group	EPS
22	ENVIRONMENTAL CONTROL	ECS
22	SYSTEM groups	
22	INSTRUMENTS-ESS group	ECS
22	INSTRUMENTS-NONESS BUS	EPS
22	INSTRUMENTS-NONESS	T/C
22	INSTRUMENTS-PAM XMTR NONESS	T/C
22	INSTRUMENTS-SCIEN	EXP
22	GAS ANAL	ECS
23	AREA A	MISC
23	AREA B	C&W
23	AREA C	T/C
24	AREA A	SEQ
24	AREA B	SCS
24	DIRECT O <sub>2</sub>	ECS
25	POSTLANDING FLOAT BAG 1 PL BUS & POSTLANDING FLOAT BAG 1, 2 & 3 switches	MISC
25	POSTLANDING VENT FAN PL BUS	ECS, MISC
25	FLOAT BAG 2	
25	POSTLANDING VENT FAN HIGH LOW OFF	ECS
25	POST LANDING-VENT FAN group	ECS
25	POST LANDING - ANTENNA	T/C
25	DEPLOY group	
25	MESC LOGIC ARM A&B	SEQ
25	EVENT TIMER group	SEQ
25	COUCH ATTEN & FLOODLIGHTS	MISC
25	STABILIZATION & CONTROL SYSTEM groups	SCS
25	BIO MED COMM group	T/C
25	SERVICE PROPULSION SYSTEM group	SPS
25	G&N SYNC	G&N
25	SPS GAUGING	SPS
25	AC SNSR SIG group	EPS
25	REACTION CONTROL SYS group	RCS
25	CAUT/WARN	C&W
25	EDS group	SEQ
25	ELS group	SEQ
25	AREA A	MISC
26	AREA B	SEQ
26	AREA C except CM RCS He DUMP	T/C
26	CM RCS He DUMP	RCS

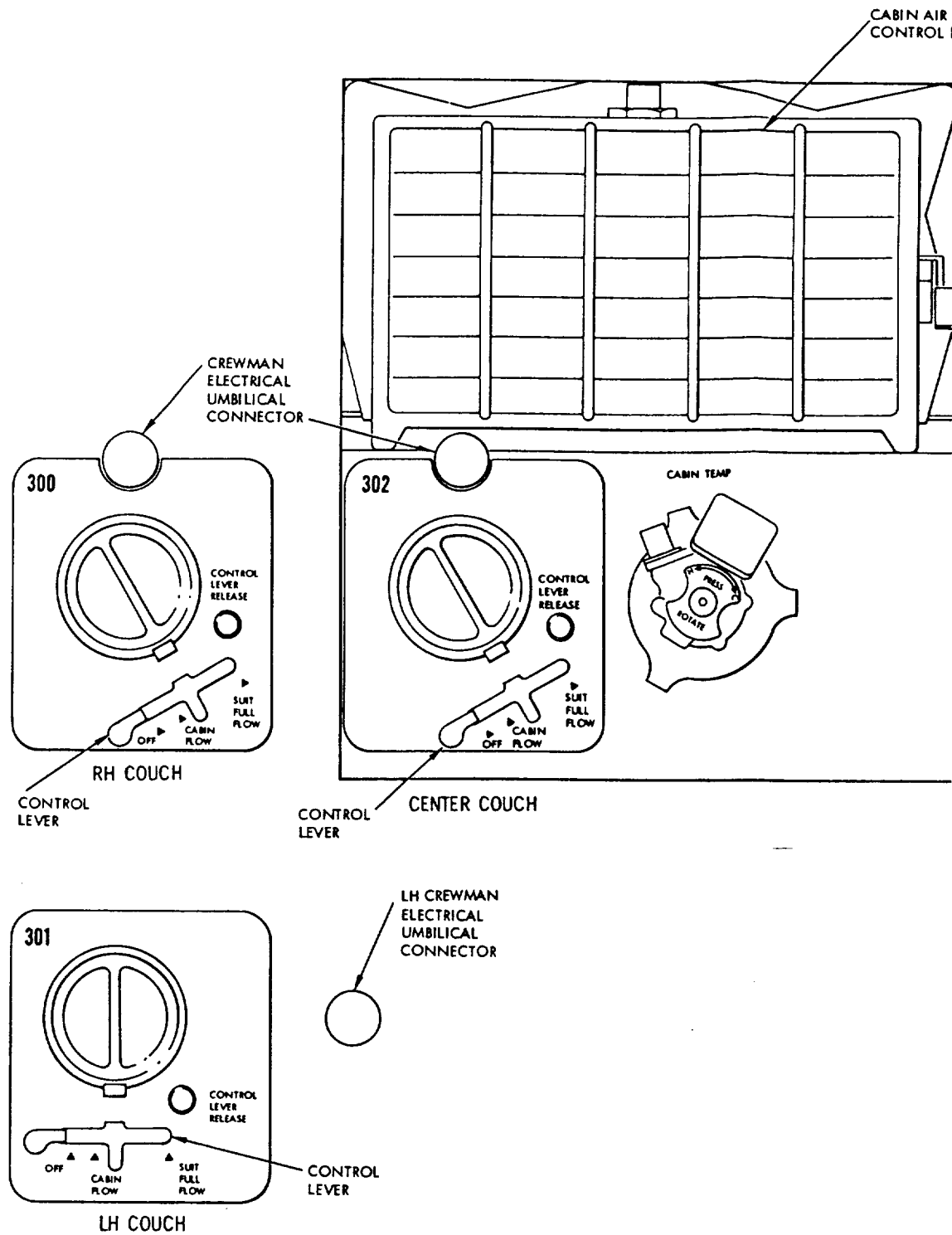
21

5M-2A-672 J

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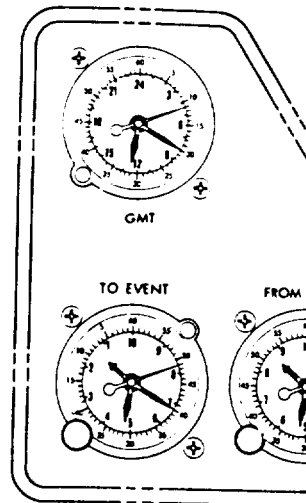
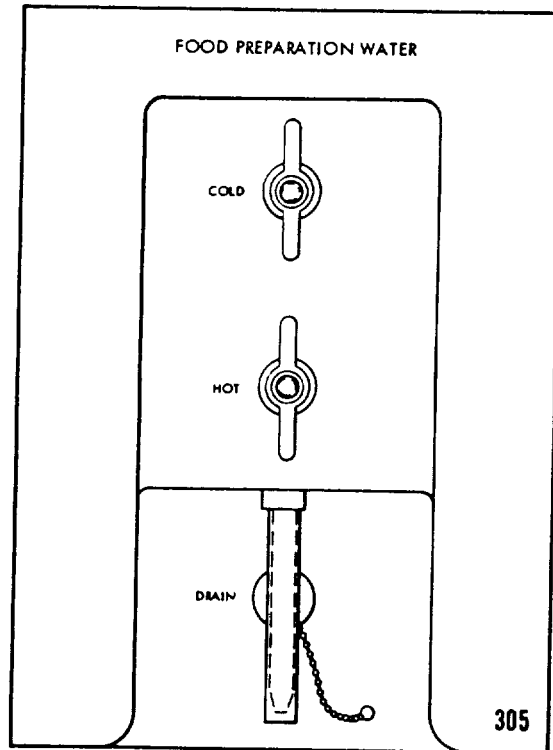
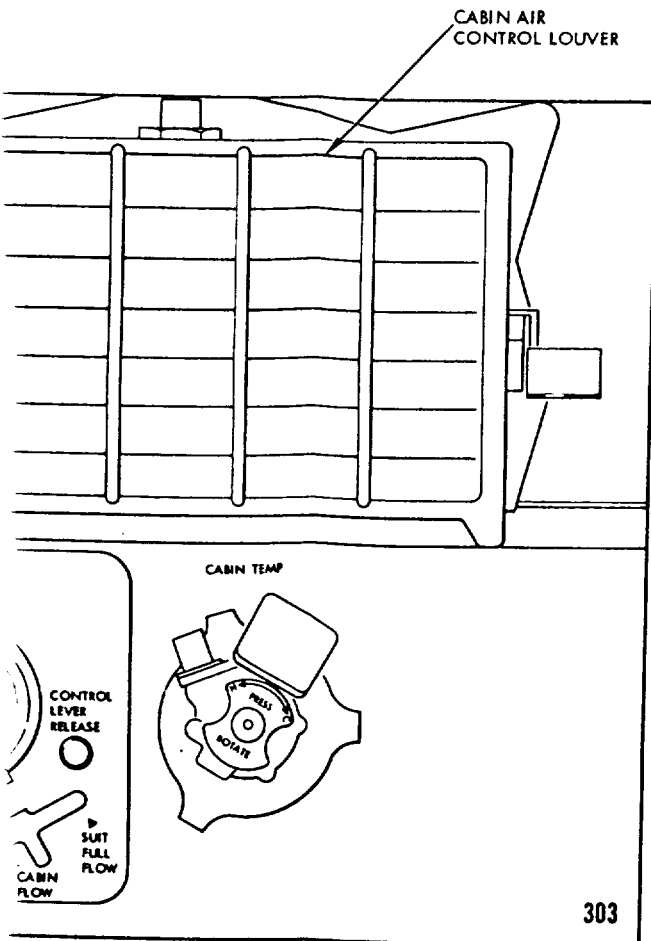
Figure 3-1. Controls and Displays (Sheet 1 of 3)





FOLDOUT FRAME 1

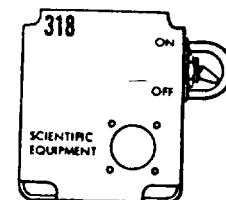




CH



304



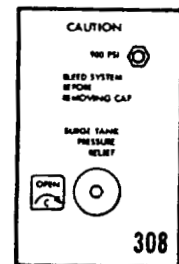
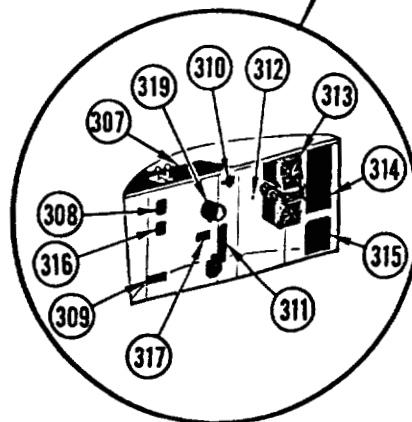
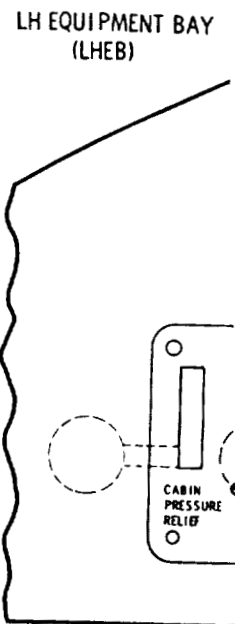
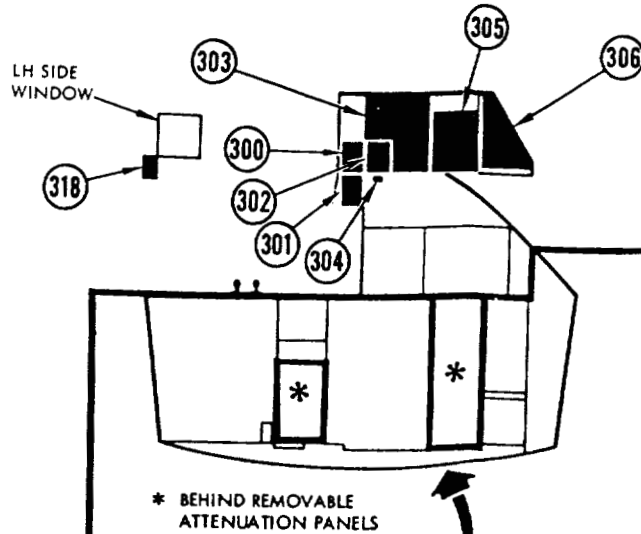
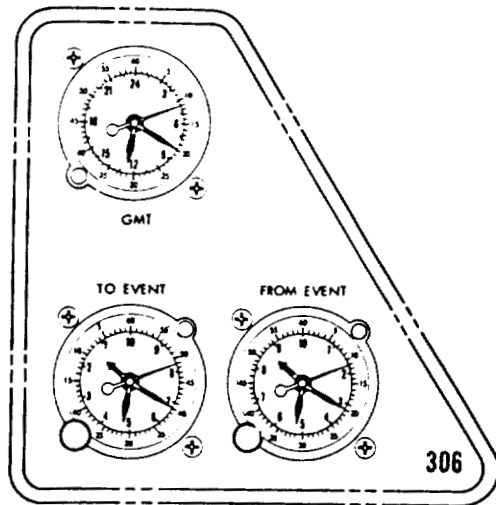
LH UTILITY PLUG

LHFEB INDEX	
PANEL NO.	PANEL NAME AND SY
304	DRINKING WATER SUPPLY SHU (UNDERSIDE OF FWD EQUIPMI
300, 301, 302	SUIT CONNECTOR PANEL (3) (
303	CABIN TEMPERATURE CONTROL
305	FOOD PREPARATION WATER SU
306	CLOCK AND EVENT TIMERS PA
318	SCIENTIFIC EQUIPMENT RECEPTION SWITCH (EXP)

FOLDOUT FRAME

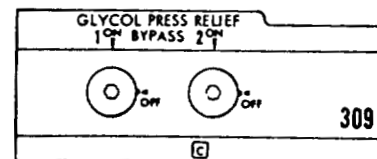
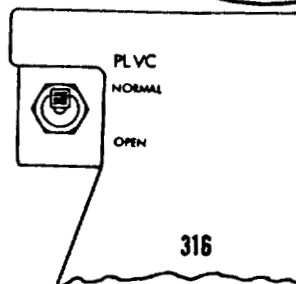
2

1000



PAN NO
305
306
307
315
310
312
313
314
315
311
316
317

LHFEB INDEX	
PANEL NO.	PANEL NAME AND SYSTEM
304	DRINKING WATER SUPPLY SHUTOFF VALVE (UNDERSIDE OF FWD EQUIPMENT BAY) (ECS)
300, 301, 302	SUIT CONNECTOR PANEL (3) (ECS)
303	CABIN TEMPERATURE CONTROL PANEL (ECS)
305	FOOD PREPARATION WATER SUPPLY UNIT (ECS)
306	CLOCK AND EVENT TIMERS PANEL (MISC)
318	SCIENTIFIC EQUIPMENT RECEPTACLE SWITCH (EXP)

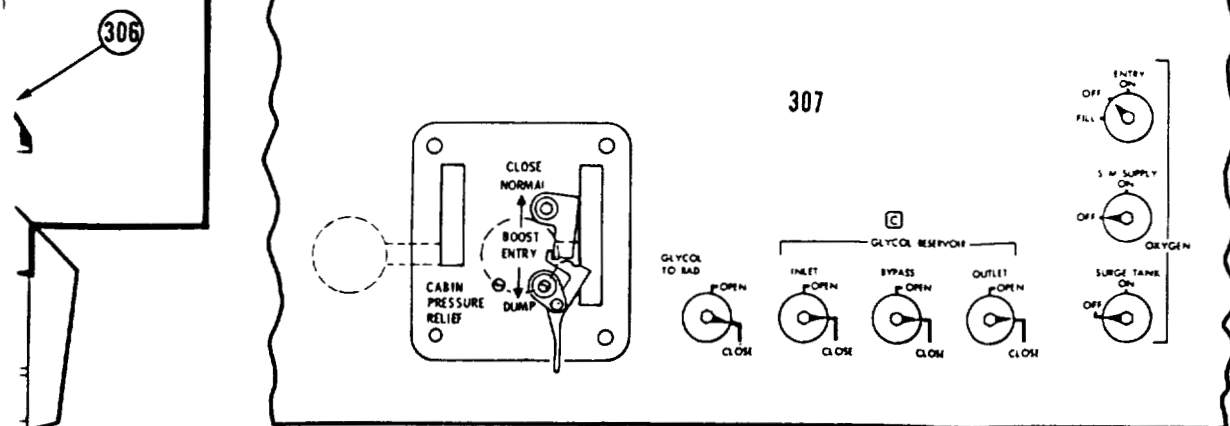




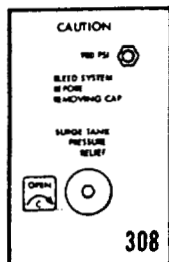


EQUIPMENT BAY  
(FEB)

LH EQUIPMENT BAY  
(LHEB)

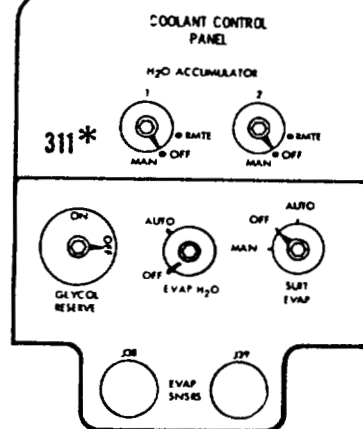
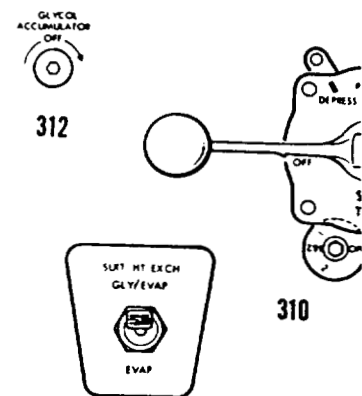
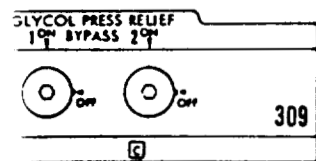
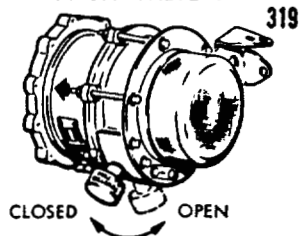


LHEB INDEX	
PANEL NO.	PANEL NAME AND SYSTEM
309	GLYCOL PRESSURE RELIEF BYPASS CONTROL PANEL (ECS)
308	SURGE TANK PRESSURE RELIEF SHUTOFF VALVE (ECS)
307	GIRTH FRAME SHELF CONTROLS (ECS)
319	SUIT CIRCUIT RETURN SHUT-OFF VALVE (ECS)
310	O <sub>2</sub> DEMAND REGULATOR AND SUIT HEAT EXCHANGER SWITCH (ECS)
312	GLYCOL ACCUM SHUTOFF VALVE (BACK OF ATTENUATOR PANEL) (ECS)
313	CO <sub>2</sub> - ODOR ABSORBER DIVERTER VALVE (ECS)
314	OXYGEN CONTROL PANEL (ECS)
315	WATER CONTROL PANEL (ECS)
311	COOLANT CONTROL PANEL (ECS)
316	PLVC CONTROL PANEL (ECS)
317	GLY EVAP WATER CONTROL BYPASS PANEL (ECS)



314  
315

SUIT CIRCUIT RETURN  
SHUT-OFF VALVE \*



EXCOLDOUT FRAME 4

Mis



CONTROLS AND DISPLAYS

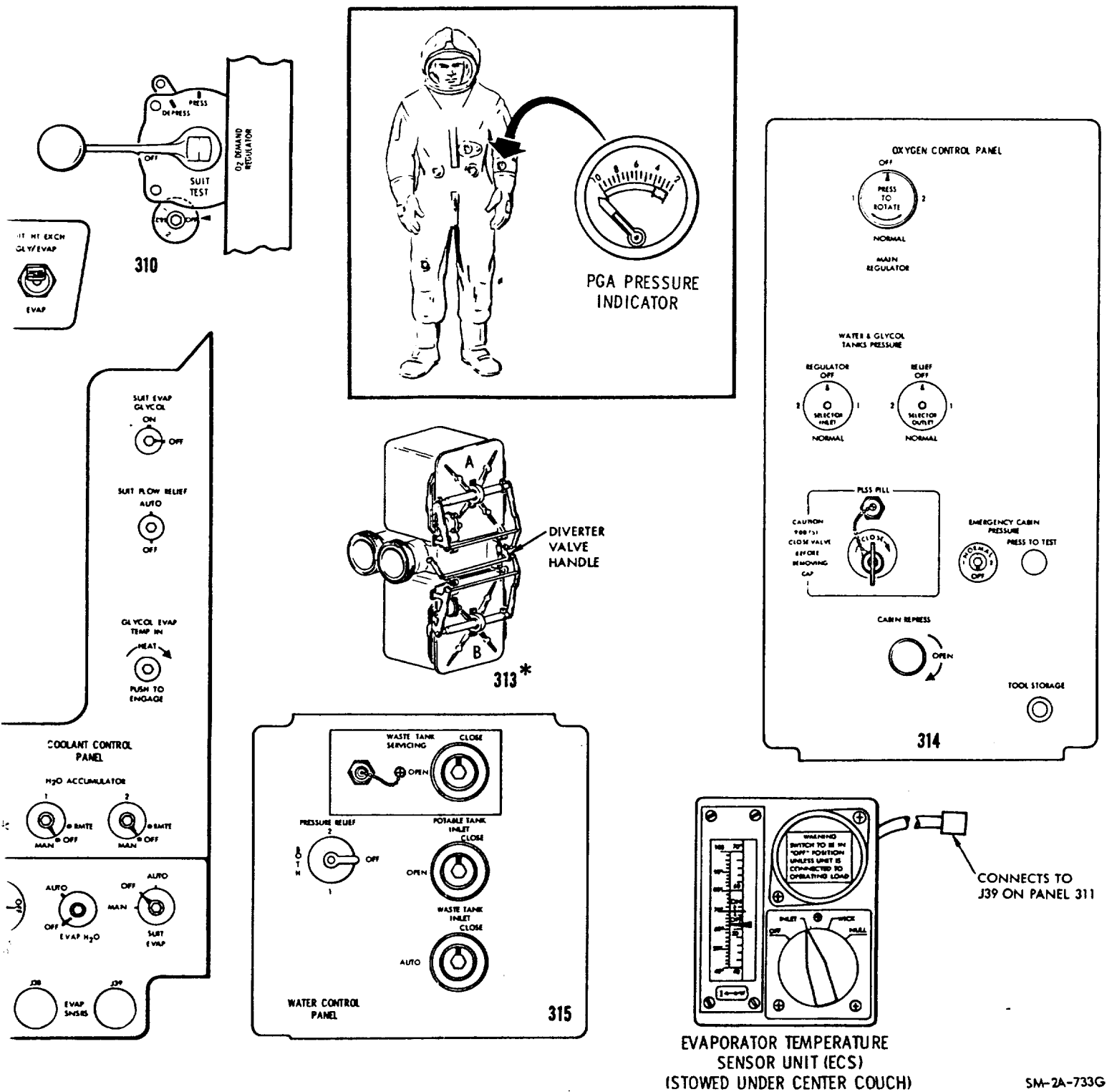
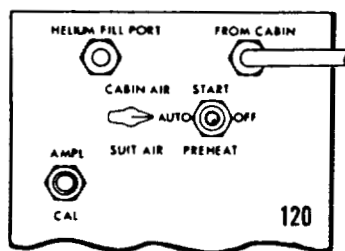
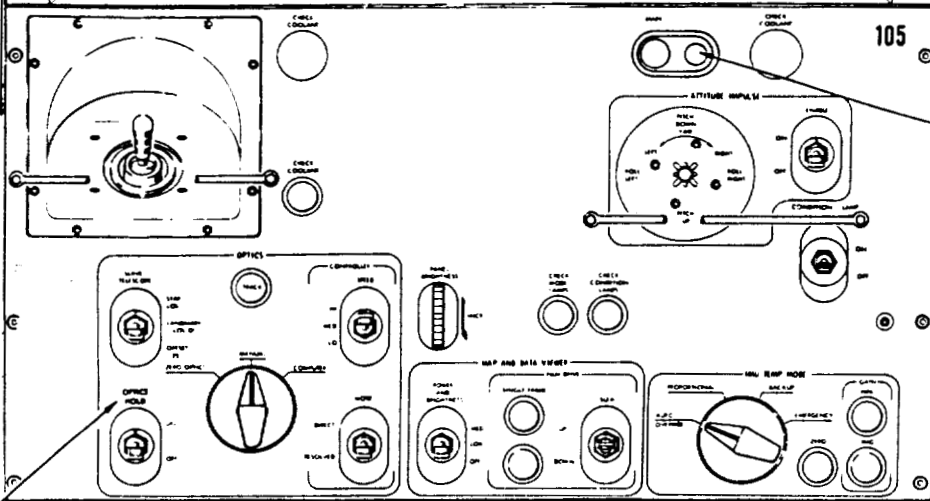
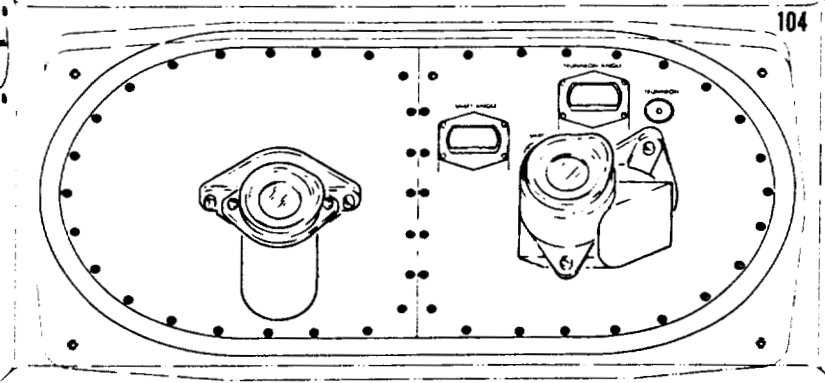
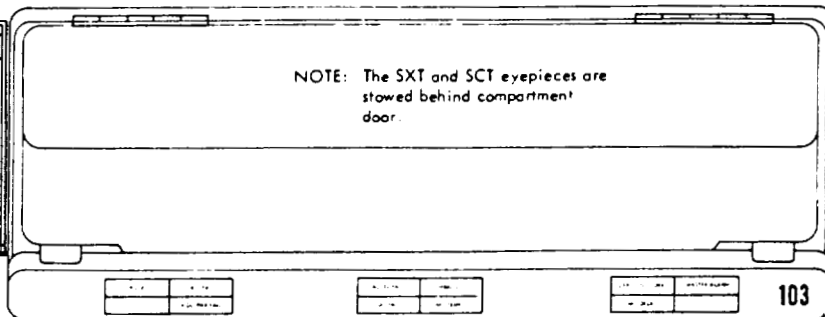
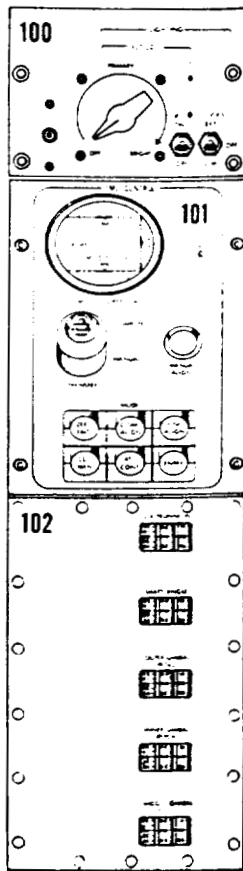


Figure 3-1. Controls and Displays (Sheet 2 of 3)

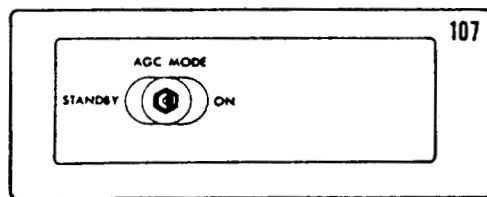
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2023-2024

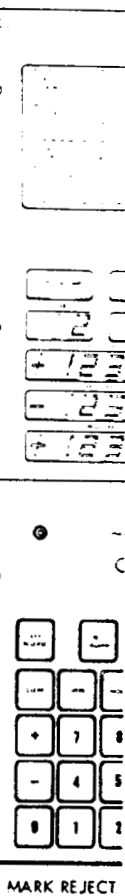
2023-2024



TRACKER POWER on SC 014



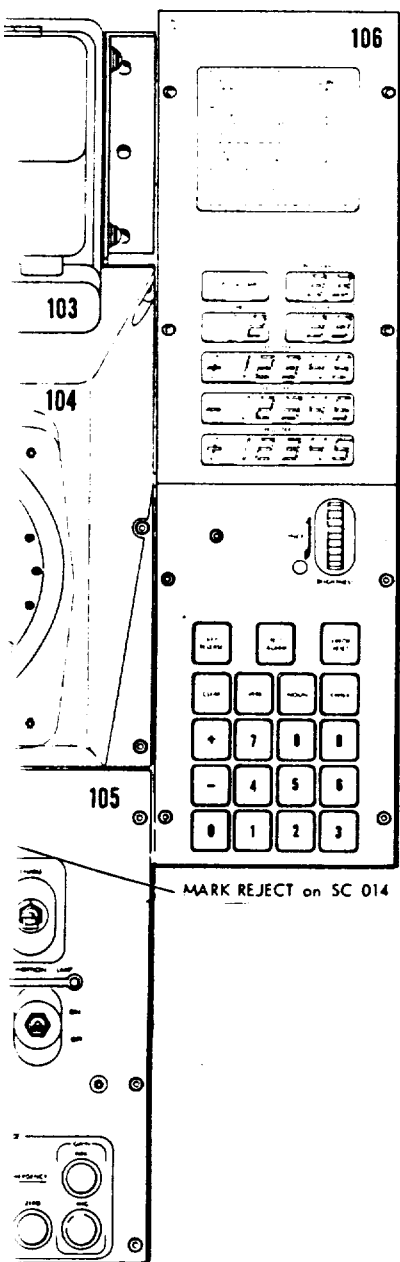
NOTE: The SXT and SCT eyepieces are stowed behind compartment door.



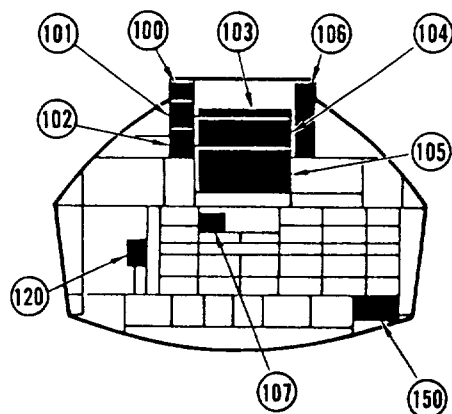
MARK REJECT

**SOLDOUT FRAME /**

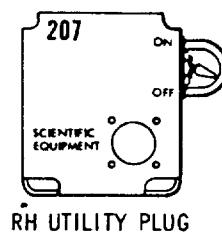
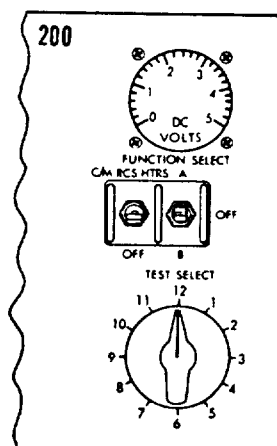
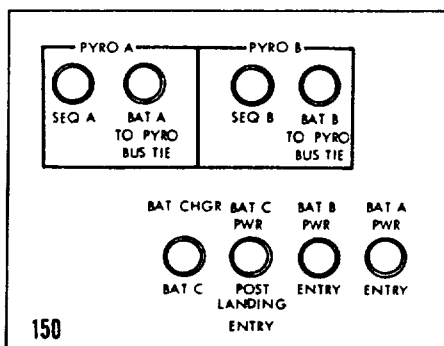




### LOWER EQUIPMENT BAY (LEB)

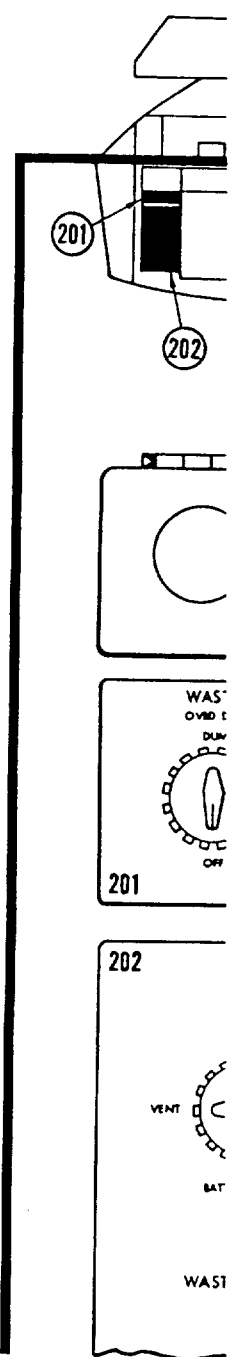


LEB INDEX		
PANEL NO.	CONTROL OR DISPLAY	SYSTEM
101 THRU 107	All controls & displays	G&N
100	LIGHTING	MISC
150	Top row	SEQ
150	Bottom row	EPS
120	All controls	ECS



RHFE INDEX		
PANEL NO.	CONTROL OR DISPLAY	SYSTEM
200	DC VOLTS, FUNCTION SELECT, and TEST SELECT	EPS
200	C/M RCS HTRS	RCS
207	SCIENTIFIC EQUIPMENT RECEPTACLE SWITCH	

RH FWD

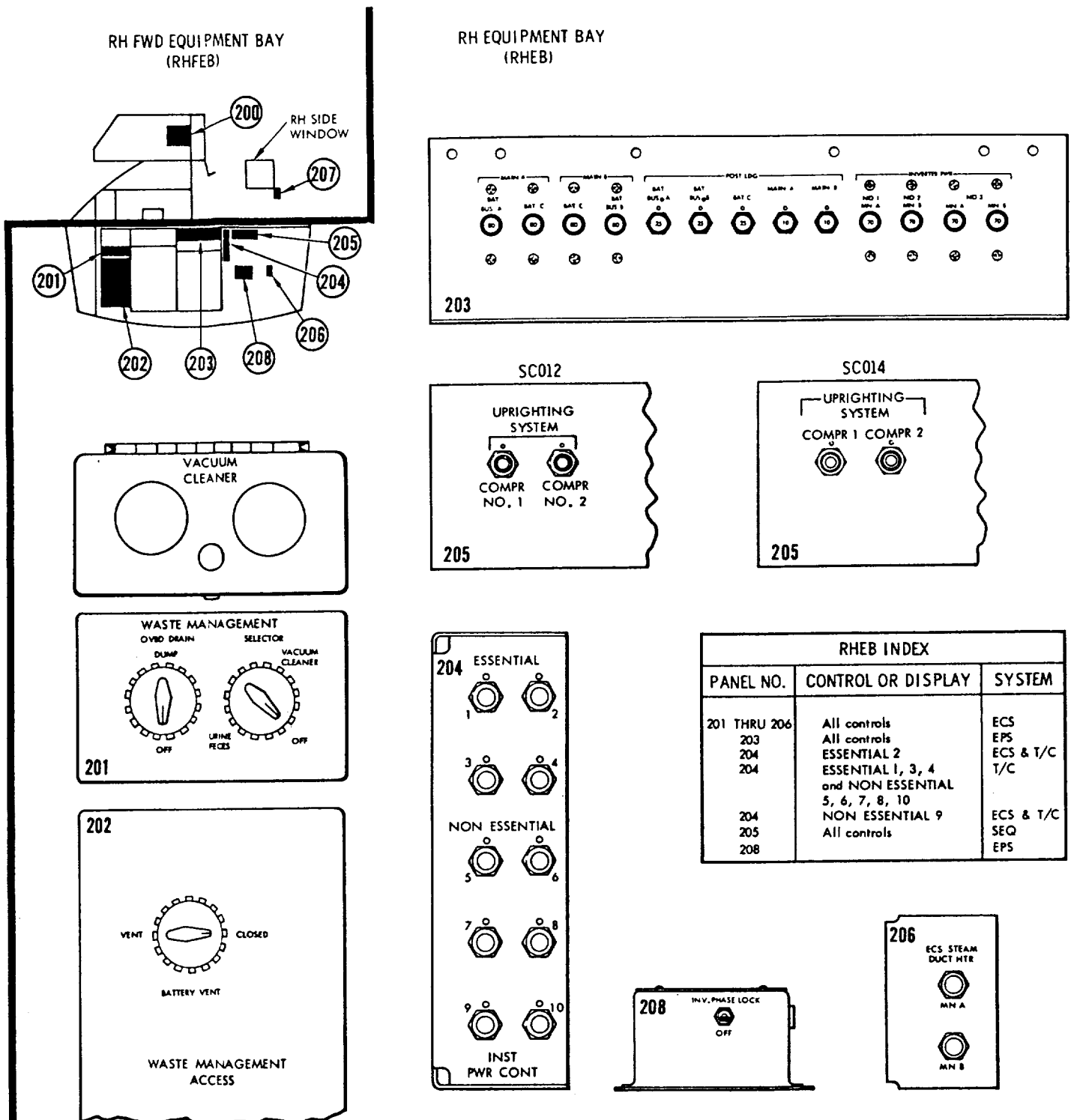






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Figure 3-1. Controls and Displays (Sheet 3 of 3)



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PERFORMANCE

SECTION 4

PERFORMANCE

INTRODUCTION.

This section contains information on crew display instrument markings, instrument accuracy consumable requirements, thrusting data (as available), and S/C operational constraints and limitations.

4.1

CREW DISPLAY INSTRUMENT MARKINGS AND ACCURACY DATA.

Paragraphs 4.1.1 through 4.1.7.4 include information on instrument markings and instrument accuracy. Adjoining tabular lists provide accuracy data for each indicator scale and list the measurement number of the signal which is monitored on each indicator scale. Some indicators can, by selection, monitor more than one signal; in which case, the measurement number of all signals monitored by the indicator are listed. Selector switch and indicator functions are covered in detail in section 2.

Some of the system indicators shown in the associated illustrations (figures 4-1 through 4-12) are provided with vertical or horizontal green-colored bands to show normal operating ranges, vertical yellow bands to show permissible operating ranges requiring caution, and horizontal red bands or lines to show system limitations. The color markings, operating ranges, and limitations for these system indicators are as follows:

System	Indicator Scale	Color Marking	Operating Range or Limitation
SPS (MDC-20) (figure 4-1)	PROP TEMP	Red	80°F (upper limit) and -40°F (lower limit)
	PRESSURE-FUEL	Green	170 to 195 psia (normal band)
	PRESS-OX	Green	Same as PRESSURE-FUEL scale.

CREW DISPLAY INSTRUMENT MARKINGS AND ACCURACY DATA

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System	Indicator Scale	Color Marking	Operating Range or Limitation
SPS (MDC-3) (figure 4-11)	PRESSURE-ENG INLET-FUEL	Green	STATIC 170 to 195 psia (normal band)  FIRE 135 to 165 psia (normal band)
	PRESSURE-ENG INLET-OX	Green	Same as PRESSURE-ENG INLET-FUEL scale.
	L/V AOA/SPS P <sub>c</sub> indicator	Green	SPS FIRE 65 to 125% (normal band)
	TANK PRESSURE- H <sub>2</sub> -1	Green	230 to 265 psia (normal band)
	TANK PRESSURE- H <sub>2</sub> -2	Green	Same as TANK PRESSURE-H <sub>2</sub> -1 scale.
	TANK PRESSURE- O <sub>2</sub> -1	Green	865 to 935 psia (normal band)
	TANK PRESSURE- O <sub>2</sub> -2	Green	Same as TANK PRESSURE-O <sub>2</sub> -1 scale
	FUEL CELL-FLOW- H <sub>2</sub>	Green	0.03 to 0.15 lb/hr (normal band)
	FUEL CELL-FLOW- O <sub>2</sub>	Green	0.25 to 1.20 lb/hr (normal band)
	FUEL CELL-MODULE TEMP-SKIN	Green	385° to 495°F (normal band)
ECS (MDC-13) (figure 4-9)	FUEL CELL-MODULE TEMP-COND EXH	Green	157.5° to 172.5°F (normal band)
	PRESS GLY DISCH	Green	35 to 55 psia (normal band)
	TEMP-SUIT	Green	45° to 65°F (normal band)
	PRESS-SUIT	Red	3.4 psia (low limit line)

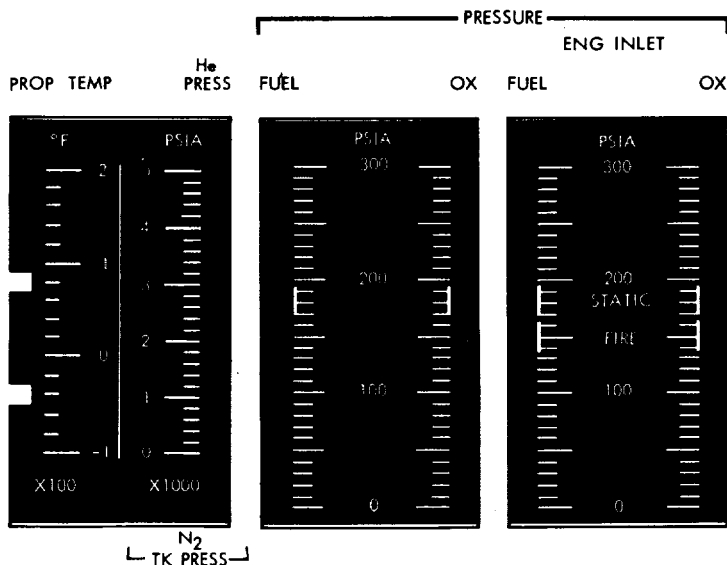
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System	Indicator Scale	Color Marking	Operating Range or Limitation
PGA (figure 4-9)	PRESS-CABIN	Red	4.7 psia (low limit line)
	PART PRESS-CO <sub>2</sub>	Red Yellow	15 mm Hg (high limit line) 7.6 to 15 mm Hg (caution band)
	PGA pressure indicator	Red Green	2.0 to 3.5 psia (emergency band) 3.5 to 10 psia (normal band)

4.1.1 SERVICE PROPULSION SYSTEM INDICATORS.

Instrument markings for the SPS indicators (MDC-20) are shown in figure 4-1. The indicators present a visual display of SPS temperatures and pressures. Visual displays of SPS fuel and oxidizer remaining aboard the S/C are shown in the adjacent OXID-FUEL QUANTITY display windows (as selected by the SPS quantity SENSOR switch). (Refer to section 3.)



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Figure 4-1. Service Propulsion System Indicators

CREW DISPLAY INSTRUMENT MARKINGS AND ACCURACY DATA

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The accuracy for each indicator scale and the measurement number of the associated signal is as follows:

Indicator Scale	Measurement Number	Indicator Accuracy
PROP TEMP	SP 0002 T	±5°F at 75°F ±10°F at 0° and 150°F
He PRESS	SP 0001 P	±100 psia at 75°F ±150 psia at 0° and 150°F
Tk PRESS-N <sub>2</sub>	SP 0600 P (Primary) SP 0601 P (Secondary)	±100 psia at 75°F ±150 psia at 0° and 150°F
PRESSURE-FUEL	SP 0006 P	±5 psia at 75°F ±10 psia at 0° and 150°F
PRESSURE-OX	SP 0003 P	±5 psia at 75°F ±10 psia at 0° and 150°F
PRESSURE-ENG INLET-FUEL	SP 0010 P	±5 psia at 75°F ±10 psia at 0° and 150°F
PRESSURE-ENG INLET-OX	SP 0009 P	±5 psia at 75°F ±10 psia at 0° and 150°F

4.1.2 REACTION CONTROL SYSTEM INDICATORS.

Instrument markings for the S/M and C/M RCS indicators (MDC-12) are shown in figure 4-2. The indicators present a visual display of system temperatures and pressures. Visual displays of S/M RCS fuel and oxidizer remaining are shown on the adjacent PROPELLANT QUANTITY indicator (as selected by the RCS INDICATORS switch). (Refer to section 3.)

The accuracy for each indicator scale and the measurement number of the associated signal is as follows:

Indicator Scale	Measurement Number	Indicator Accuracy
S/M RCS-TEMP PKG	SR 5065 T (Quad A) SR 5066 T (Quad B) SR 5067 T (Quad C) SR 5068 T (Quad D)	±5°F at 75°F ±10°F at 0° and 150°F

CREW DISPLAY INSTRUMENT MARKINGS AND ACCURACY DATA

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Indicator Scale	Measurement Number	Indicator Accuracy
S/M RCA-PRESS-H <sub>e</sub>	SR 5001 P (Quad A) SR 5002 P (Quad B) SR 5003 P (Quad C) SR 5004 P (Quad D)	±100 psia at 75°F ±150 psia at 0° and 150°F
S/M RCS-PRESS-MANF	SR 5729 P (Quad A) SR 5776 P (Quad B) SR 5817 P (Quad C) SR 5830 P (Quad D)	At 75°F, ±5 psia from 140 to 340 psia and ±10 psia over balance of scale. At 0° and 150°F, ±10 psia from 145 to 340 psia and ±15 psia over balance of scale.
S/M RCS-TEMP H <sub>e</sub>	SR 5013 T (Quad A) SR 5014 T (Quad B) SR 5015 T (Quad C) ST 5016 T (Quad D)	Same as S/M RCS-PRESS-MANF indicator
C/M RCS-H <sub>e</sub> TEMP	CR 0003 T (System A) CR 0004 T (System B)	±5°F at 75°F ±10°F at 0° and 150°F
C/M RCS-PRESS-H <sub>e</sub>	CR 0001 P (System A) CR 0002 P (System B)	±100 psia at 75°F ±150 psia at 0° and 150°F
C/M RCS-PRESS-F	CR 0005 P (System A) CR 0006 P (System B)	Same as S/M RCS-PRESS-MANF indicator.
C/M RCS-PRESS-OX	CR 0011 P (System A) CR 0012 P (System B)	Same as S/M RCS-PRESS-MANF indicator.

4.1.3 ELECTRICAL POWER SYSTEM INDICATORS.

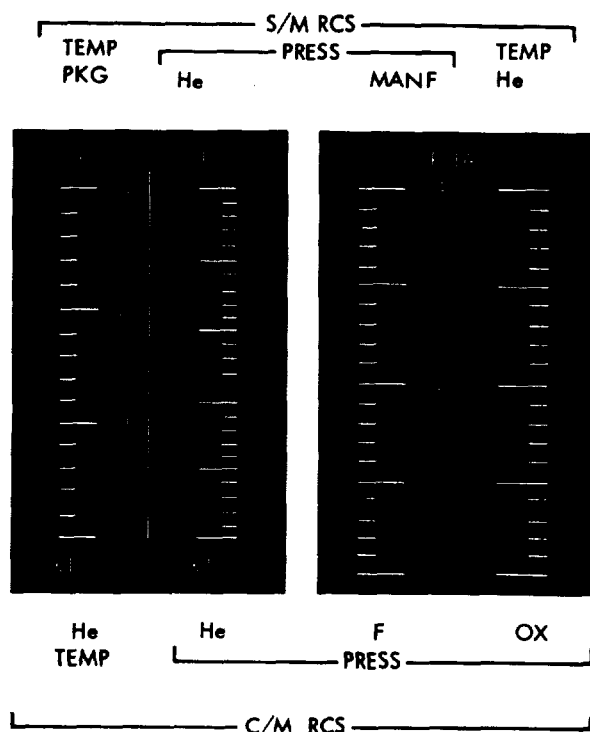
4.1.3.1 EPS (Cryogenic Storage) Tank Pressure Indicators.

Instrument markings for the EPS (cryogenic storage) tank pressure indicators (MDC-13) are shown in figure 4-3. The accuracy for each indicator scale and the measurement number of the associated signal is as follows:

NOTE TANK PRESSURE-O<sub>2</sub>-1 scale is used to display cryogenic storage tank 1 pressure or ECS surge tank pressure as selected by O<sub>2</sub> PRESS IND toggle switch located immediately below the display.

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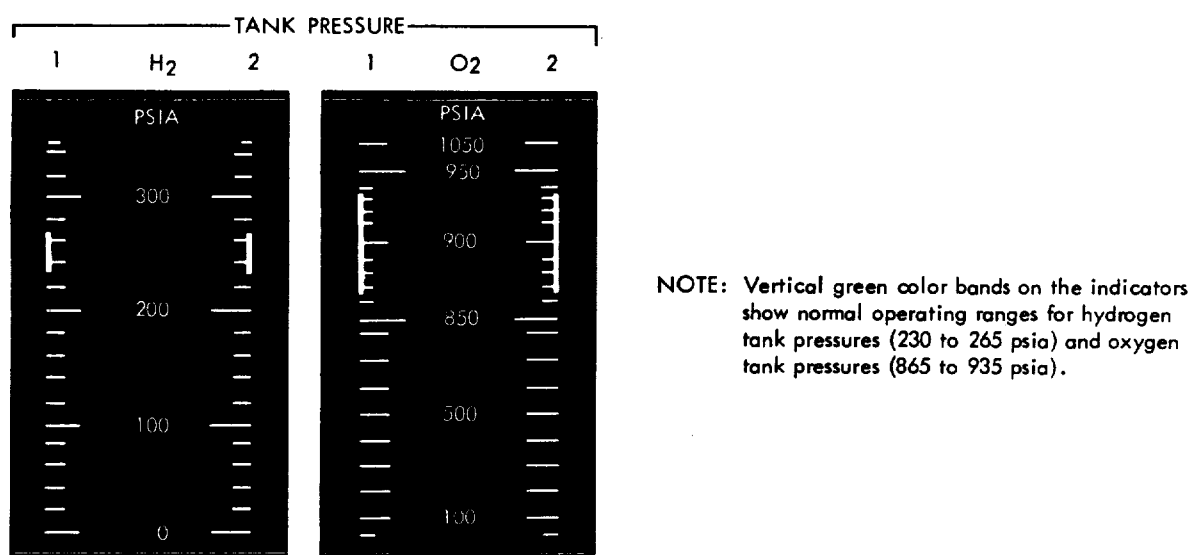
Figure 4-2. S/M and C/M Reaction Control System Indicators

Indicator Scale	Measurement Number	Indicator Accuracy
TANK PRESSURE-H <sub>2</sub> -1	SF 0039 P	±5 psia at 75°F ±10 psia at 0° and 150°F
TANK PRESSURE-H <sub>2</sub> -1	SF 0040 P	Same as TANK PRESSURE-H <sub>2</sub> -1 indicator.
TANK PRESSURE-O <sub>2</sub> -1	SF 0037 P (Storage tank) CF 0006 P (Surge tank)	At 75°F, ±5 psia at 850 to 950 psia and ±3% of remaining scale. At 0° and 150°F, ±10 psia at 850 to 950 psia and 4% of remaining scale.
TANK PRESSURE-O <sub>2</sub> -2	SF 0038 P	Same as TANK PRESSURE-O <sub>2</sub> -2 indicator.



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SM-2A-690D

Figure 4-3. EPS (Cryogenic Storage) Tank Pressure Indicators

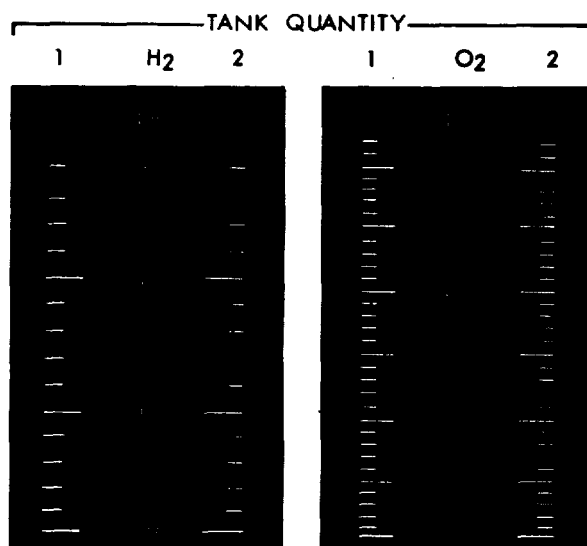
4.1.3.2 EPS (Cryogenic Storage) Tank Quantity Indicators.

Instrument markings for the EPS (cryogenic storage) tank quantity indicator (MDC-13) are shown in figure 4-4. The accuracy for each indicator scale and the measurement number of the associated signal is as follows:

Indicator Scale	Measurement Number	Indicator Accuracy
TANK QUANTITY-H <sub>2</sub> -1	SF 0030 Q	±0.5 lb at 75°F ±1.0 lb at 0° and 150°F
TANK QUANTITY-H <sub>2</sub> -2	SF 0031 Q	Same as TANK QUANTITY-H <sub>2</sub> -1 indicator.
TANK QUANTITY-O <sub>2</sub> -1	SF 0032 Q	±5.0 lb at 75°F ±10.0 lb at 0° and 150°F
TANK QUANTITY-O <sub>2</sub> -2	SF 0033 Q	Same as TANK QUANTITY-O <sub>2</sub> -1 indicator.

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Figure 4-4. EPS (Cryogenic Storage) Tank Quantity Indicators

4.1.3.3 EPS Fuel Cell Power Plant Indicators.

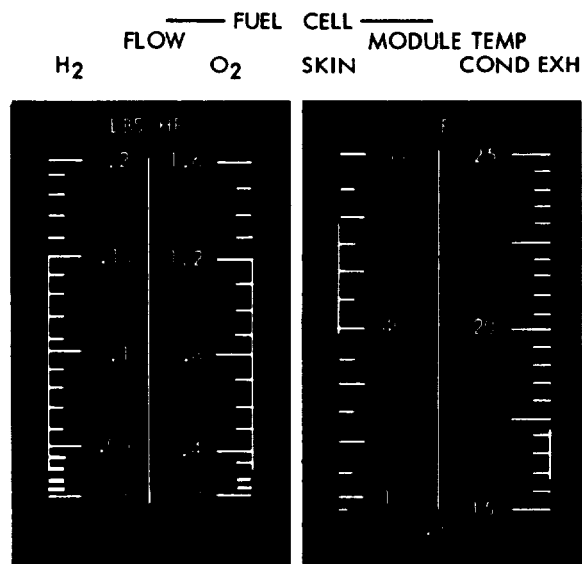
Instrument markings for the EPS fuel cell power plant indicators (MDC-18) are shown in figure 4-5. The accuracy for each indicator scale and the measurement number of the associated signal is as follows:

Indicator Scale	Measurement Number	Indicator Accuracy
FUEL CELL-FLOW-H <sub>2</sub>	SC 2139 R (F/C 1)	±0.005 lb/hr at 75°F
	SC 2140 R (F/C 2)	±0.0075 lb/hr at 0° and
	SC 2141 R (F/C 3)	150°F
FUEL CELL-FLOW-O <sub>2</sub>	SC 2141 R (F/C 1)	±0.05 hr/hr at 75°F,
	SC 2143 R (F/C 2)	and at 0° and 150°F
	SC 2144 R (F/C 3)	
FUEL CELL-MODULE TEMP-SKIN	SC 2084 T (F/C 1)	At 75°F, ±7°F for 400° to
	SC 2085 T (F/C 2)	550° scale and 3% of remain-
	SC 2086 T (F/C 3)	ing scale. At 0° and 150°F,
FUEL CELL-MODULE TEMP-COND EXH	SC 2081 T (F/C 1)	±14°F for 400° to 500° scale
	SC 2082 T (F/C 2)	and 3% of remaining scale.
	SC 2083 T (F/C 3)	
	SC 2081 T (F/C 1)	±3° at 75°F
	SC 2082 T (F/C 2)	±5°F at 0° and 150°F
	SC 2083 T (F/C 3)	

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NOTE: Vertical green color bands on the indicators show normal operating ranges for hydrogen flow (0.03 to 0.15 lb/hr), oxygen flow (0.25 to 1.20 lb/hr), module skin temperature (385° to 495°F), and the condenser exhaust temperature (157.5° to 172.5°F).

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Figure 4-5. EPS Fuel Cell Indicators

4.1.3.4 EPS Volts, Amperes, and Frequency Meters.

Instrument markings for the EPS-volts, amperes, and frequency meters (MDC-18) are shown in figure 4-6. The accuracy for each indicator scale and the measurement number of the associated signal is as follows:

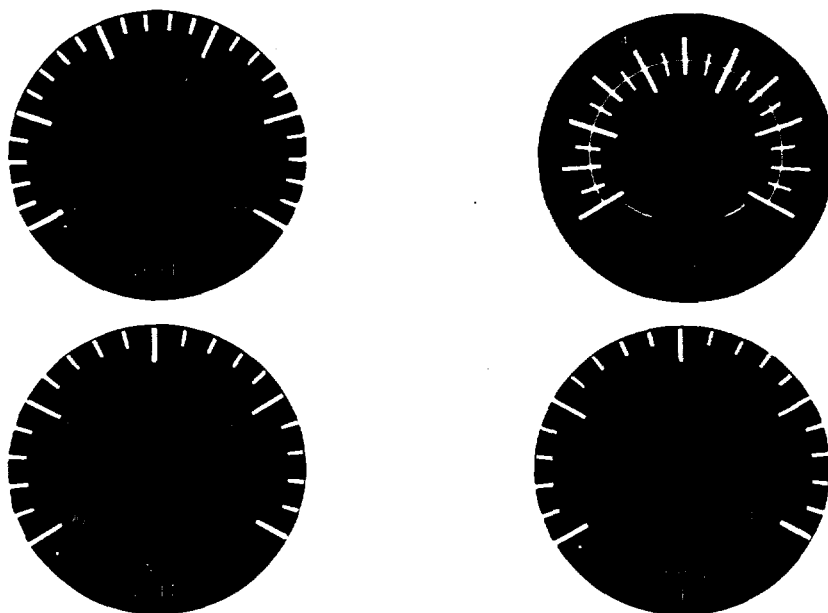
Indicator Scale	Measurement Number	Indicator Accuracy
DC VOLTS	CC 0206 V (Main Bus A)	At 75°F, $\pm 0.25$ volts for 25 to 37 volts scale and $\pm 1.0$ volt for balance of scale. At 0° and 150°F, $\pm 0.5$ volts for 25 to 37 volts scale and $\pm 1.0$ volt for balance of scale.
	CC 0207 V (Main Bus B)	
	CC 0210 V (Bat Bus A)	
	CC 0211 V (Bat Bus B)	
	CC 0212 V (Post Ldg Bat)	
	CC 0214 V (Bat Charger Output)	
	CC 0227 V (Pyro Bat A)	
	CC 0228 V (Pyro Bat B)	
DC AMPS	CC 0222 C (Bat Bus A)	$\pm 1.0\%$ of full scale at 75°F $\pm 2.0\%$ of full scale at 0° to 150°F
	CC 0223 C (Bat Bus B)	
	CC 0224 C (Post Ldg Bat)	
	SC 2113 C (F/C 1 Output)	
	SC 2114 C (F/C 2 Output)	
	SC 2115 C (F/C 3 Output)	

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Figure 4-6. EPS Volts, Amperes, and Frequency Meters

Indicator Scale	Measurement Number	Indicator Accuracy
CHGR (Inner Scale)	CC 0215 C (Bat Charger Output)	Same as DC AMPS scale
AC VOLTS	CC 0200 V (Bus 1 ØA)	Between 0° and 150°F, ±1.0 volt for the 105 and 125 volts scale and ±2.0 volts for balance of scale. At 0° and 150°F, ±2.0 volts for the 105 and 125 volts scale.
	CC 0201 V (Bus 1 ØB)	
	CC 0202 V (Bus 1 ØC)	
	CC 0203 V (Bus 2 ØA)	
	CC 0204 V (Bus 2 ØB)	
	CC 0205 V (Bus 2 ØC)	
FREQ CPS	CC 0213 F (Bus 1 ØA)	From 50° to 110°F, ±1 cycle at 400 cycles. From 0° to 150°F, ±2 cycles at 400 cycles and ±2.5 cycles for balance of scale.
	CC 0181 F (Bus 1 ØB)	
	CC 0182 F (Bus 1 ØC)	
	CC 0217 F (Bus 2 ØA)	
	CC 0183 F (Bus 2 ØB)	
	CC 0184 F (Bus 2 ØC)	

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4.1.4 ENVIRONMENTAL CONTROL SYSTEM INDICATORS.

4.1.4.1 ECS Pressure and Slow-Rate Indicators.

Instrument markings for the ECS pressure and rate-of-flow indicator (MDC-13) are shown in figure 4-7. The accuracy for each indicator scale and the measurement number of the associated signal is as follows:

Indicator Scale	Measurement Number	Indicator Accuracy
GLY EVAP STEAM PRESS	CF 0034 P	±5% of full scale between 0° and 150°F
PRESS GLY DISCH	CF 0016 P	Same as above.
FLOW O <sub>2</sub>	CF 0035 R	Same as above.
ΔP SUIT COMPR	CF 0115 P	Same as above.

4.1.4.2 ECS Quantity and Outlet Temperature Indicators.

Instrument markings for the ECS quantity and outlet temperature indicators (MDC 13 and 14) are shown in figure 4-8. The accuracy for each indicator scale and the measurement number of the associated signal is as follows:

Indicator Scale	Measurement Number	Indicator Accuracy
GLY ACCUM-QUANTITY	CF 0019 Q	±5% full-scale 0° to 150°F
WATER QUANTITY	CF 0010 Q (Potable Water) CF 0009 Q (Waste Water)	Same as above.
ECS RAD-OUTLET TEMP	CF 0020 T	Same as above.
GLY EVAP-OUTLET TEMP	CF 0018 T	Same as above.
ECS RAD OUT TEMP-1	SF 0671 T	Same as above.
ECS RAD OUT TEMP-2	SF 0672 T	Same as above.

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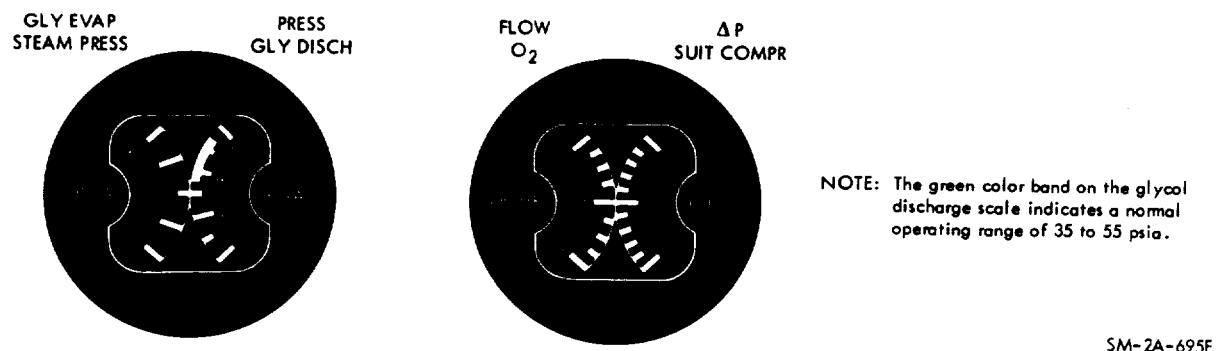


Figure 4-7. ECS Pressure and Flow Indicators

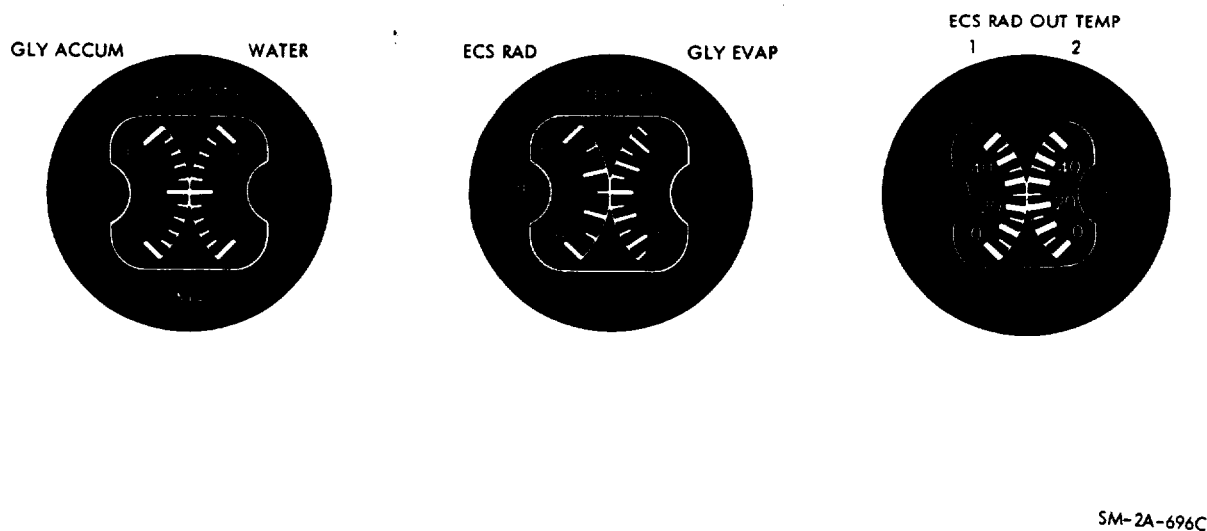


Figure 4-8. ECS Quantity and Outlet Temperature Indicators

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4.1.4.3 ECS Suit and Cabin Temperature/Pressure Indicators.

Instrument markings for the ECS suit and cabin temperature/pressure indicators are shown in figure 4-9. The accuracy for each indicator scale and the measurement number of the associated signal is as follows:

Indicator Scale	Measurement Number	Indicator Accuracy
TEMP-SUIT	CF 0008 T	$\pm 2.5^{\circ}\text{F}$ overall at $0^{\circ}$ to $150^{\circ}\text{F}$ .
TEMP-CABIN	CF 0002 T	Same as above.
PRESS-SUIT	CF 0012 P	At $75^{\circ}\text{F}$ , $\pm 0.25$ psia between 0 and 6 psia and $\pm 3\%$ for remainder of scale. At $0^{\circ}$ and $150^{\circ}\text{F}$ , $\pm 0.375$ psia between 0 and 6 psia, and $\pm 4\%$ for remainder of scale.
PRESS-CABIN	CF 0001 P	Same as PRESS-SUIT scale.
PART PRESS-CO <sub>2</sub>	CF 0005 P	At $75^{\circ}\text{F}$ , $\pm 0.5$ mm between 0 and 15 mm Hg, and $\pm 1.0$ mm for remainder of scale. At $0^{\circ}$ and $150^{\circ}\text{F}$ , $\pm 1.0$ mm between 0 and 15 mm Hg, and 1.5 mm for remainder of scale.
PGA Pressure Indicator	None	$\pm 2$ psia overall at normal temperature range.

4.1.5 TELECOMMUNICATION SYSTEM METERS.

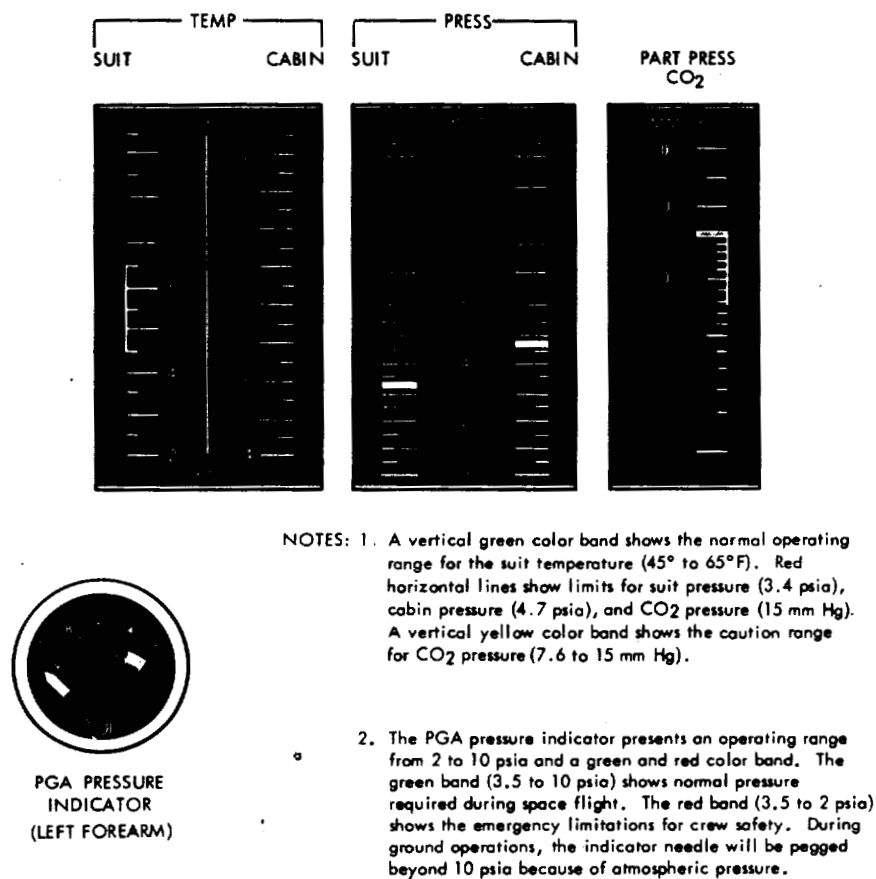
Instrument markings for the telecommunication system meters are shown in figure 4-10.

4.1.5.1 Auxiliary DC VOLTS Meter.

The auxiliary DC VOLTS meter, located on RHFE-200 (figure 4-10), is used to monitor selected measurements for which there is either no other crew display or the crew display is an event indicator capable of displaying only in-tolerance and out-of-tolerance conditions. The voltmeter is used in conjunction with the adjacent FUNCTION SELECT and TEST SELECT

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Figure 4-9. ECS Suit and Cabin Temperature/Pressure Indicators



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Figure 4-10. Telecommunication System Meters



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switches to monitor 13 EPS, 6 RCS, 4 G&N and 1 ECS analog measurements. Refer to Controls and Displays (section 3) for information on which measurements are selected for monitoring by the auxiliary DC VOLTS meter.

The voltmeter provides a reading between 0 and 5 volts of the selected measurement. By use of a voltmeter conversion chart an interpolation of the value for the selected measurement can be made. (Refer to section 2.)

NOTE The accuracy of the auxiliary DC VOLTS meter (for the full scale) is  $\pm 1$  percent at 75°F and  $\pm 2$  percent at 0° and 150°F.

4.1.5.2 S-Band ANT Meter.

The S-Band ANT meter, on MDC-19 (figure 4-10), utilizes the automatic gain control (AGC) signal in the S-Band receiver to display, in a clockwise direction, the relative magnitude of signals received by the unified S-band equipment (USBE). The meter is used in determining the correct S-band antenna and S/C attitude for optimum S-band performance.

NOTE The accuracy of the S-BAND ANT meter (for the full scale) is  $\pm 5$  percent at temperatures between 0° and 150°F.

4.1.6 SEQUENTIAL SYSTEMS INDICATORS.

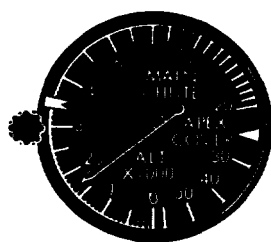
Instrument markings for the sequential systems indicators are shown in figure 4-11. The indicators present visual displays required during launch, in-flight SPS operation, and the earth landing sequence of events. (Refer to paragraphs 4.1.6.1 and 4.1.6.2.)

4.1.6.1 Barometric Pressure Indicator (Altimeter).

The barometric pressure indicator, an altimeter on MDC-1 (figure 4-11), is used in conjunction with the earth landing system (ELS) and indicates the pressure altitude of the S/C under low-altitude, low-Mach conditions. This altimeter is monitored during the earth landing phase of the mission to verify that the ELS sequencer is initiating various phases of landing system deployment at the proper pressure altitude points. A knob, located left of the altimeter dial face, is used in setting the adjacent marker (to display the corrected main parachute deploy altitude for low-altitude aborts). The adjustable marker, based

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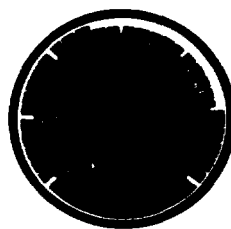
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Barometric Pressure Indicator  
(Altimeter)

NOTE:

The green band on the L/V AOA/SPS  $P_c$  indicator shows normal operating pressures (65 to 125%) for the SPS combustion chamber during engine operation in space flight.



L/V AOA/SPS  $P_c$  Indicator

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Figure 4-11. Sequential System Indicators

on barometric pressure, is set prior to launch. (Refer to paragraph 4.4.2.2 for altimeter error and C/B base pressure effects.)

NOTE The accuracy of the altimeter is  $\pm 100$  feet from 0 to 4000 feet and 5 percent of the altimeter reading from 4000 to 60,000 feet.

4.1.6.2 L/V AOA/SPS  $P_c$  Indicator.

The L/V AOA/SPS  $P_c$  indicator, on MDC-3 (figure 4-11), is used to display the launch vehicle angle of attack (in percentage of pressure from the Q-ball) during launch. After launch vehicle separation from the S/C, the gauge is used to display SPS combustion chamber pressure during engine operation. Inputs to this time-shared gauge are determined by the position of the L/V AOA/SPS  $P_c$  switch, located on the same panel.

NOTE The accuracy of the L/V AOA/ $P_c$  indicator (for the full scale) is 1 percent at 75°F and 2 percent at 0° and 150°F.

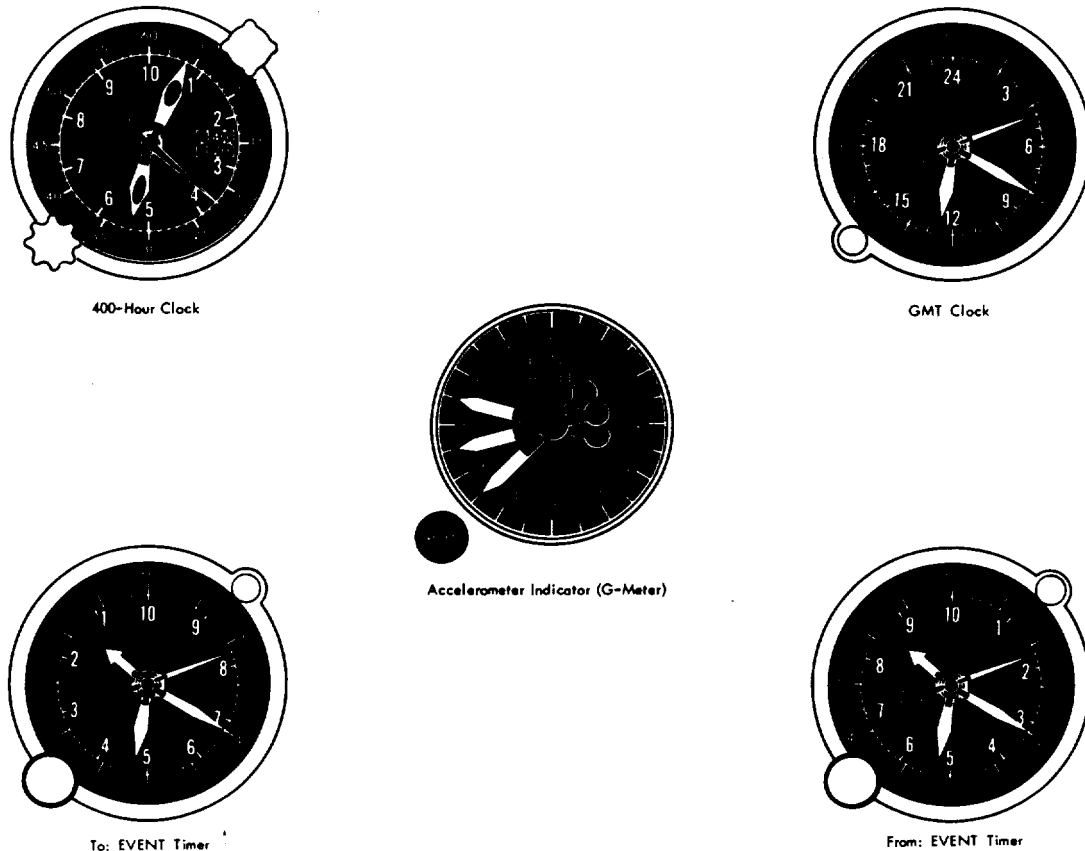
4.1.7 MISCELLANEOUS INDICATORS.

Instrument markings for mechanically operated indicators such as clocks, timers, and an accelerometer are shown in figure 4-12 and described in paragraphs 4.1.7.1 through 4.1.7.4.

NOTE The accuracy of the S/C clocks and timers at temperatures between 60° and 90°F (and zero gravity) will not exceed  $\pm 5$  seconds for 10 consecutive days (the arithmetic average of the daily rates). For environmental conditions above or below this temperature range, the average of daily rates for 5 consecutive days will not exceed 30 seconds.

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Figure 4-12. Miscellaneous Indicators

4.1.7.1 Mission-Elapsed Time (400-Hour) Clock.

The 400-hour clock, on MDC-12 (figure 4-12), has a 10-hour dial face with second, minute, and hour hands. A display window is also provided to show mission elapsed time in 10-hour increments up to 400 hours (when window display returns to 0.000). The hour and minute hands are set by a knob at the bottom left of the dial face. A knob at the top right of the dial is used to reset, start, and stop the clock. This clock is illuminated when the floodlights switch on MDC-27 is actuated.

4.1.7.2 GMT (Greenwich Mean Time) Clock.

The GMT clock, LHFEB-306 (figure 4-12), has a 24-hour dial face with standard second, minute, and hour hands. A time-set screw, at the bottom left of the dial face, is used to

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synchronize the clock with Greenwich mean time. This clock illuminates when the CLOCKS-BRT-OFF-DIM switch (LEB-98) is actuated.

4.1.7.3 TO EVENT and FROM EVENT Timers.

The TO EVENT and FROM EVENT timers, on LHFEB-306 (figure 4-12), have 10-hour dial faces with second, minute, hour, and 10-hour hands. A knob at the bottom left of each timer is used to set the timer hands. Each timer can be reset, started, or stopped by a pushbutton control at the top right of the timer. These timers illuminate when the CLOCKS-BRT-OFF-DIM switch (LEB-100) is actuated.

4.1.7.4 Accelerometer Indicator (G-Meter).

The accelerometer indicator or g meter, on MDC-2 (figure 4-12), is provided with an indicating pointer for showing S/C positive and negative g loads. In addition to the indicating pointer, there are two recording pointers (one for positive and one for negative g loads) which follow the indicating pointer to its maximum attained travel. The recording pointers will remain at the maximum positive and negative positions attained to provide a record of maximum g loads encountered. To return the recording pointers to the normal 1-g position, it is necessary to press the RESET knob on the lower left-side of the accelerometer.

NOTE The accuracy of the g meter is  $\pm 0.2$  g from 0 to 4 g's,  $\pm 0.3$  g at 6 g's,  $\pm 0.4$  g from 8 to 10 g's, and  $\pm 0.75$  g at 15 g's.

4.2 CONSUMABLE REQUIREMENTS.

Information relating to S/C 014 consumable materials for the RCS, SPS, EPS, and ECS is provided in this section. For detailed consumable data, refer Mission Modular Data Book (MMDB).

4.2.1 S/M RCS PROPELLANT CONSUMPTION DATA.

Propellant consumables utilized by the 16 S/M RCS engines provide thrust for three-axes rotational and translational control of the spacecraft (after S/C separation from the launch vehicle and until C/M-S/M separation prior to entry). The oxidizer/fuel ratio (by weight) for each engine is  $2.03 \pm 0.075:1$  at a propellant flow rate of 0.360 lb/sec. Nominal values for

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the individual S/M RCS consumables (maximum usable tank capacity of 790 pounds) are as follows:

Consumables	Storage Tank	Weight per Tank		Delivery Rate to Engine (lb/sec)
		Filled (lb)	Maximum Usable (lb)	
Nitrogen tetroxide ( $N_2O_4$ ) (oxidizer)	4	138.1	131.7	0.241
50% unsymmetrical diamethylhydrazine and 50% hydrazine (UDMH/ $N_2H_4$ ) (fuel)	4	69.7	65.8	0.119
Helium (He) (pressurant)	4	0.52	0.52	N/A

4.2.1.1 Manual Attitude Control Maneuvers

S/M RCS propellant consumption rates for manual attitude control maneuvers (proportional and direct control) are presented in figure 4-13. Assumptions applicable to the curves shown in figure 4-13 are as follows:

- The dynamic disturbances accounted for are SPS propellant slosh, the earth orbit aerodynamics and gravity gradient, ECS steam venting, and rotating EPS and ECS equipment.
- A nominal maneuver of  $50 \pm 0.5$  degrees per axis.
- This data may be ratioed to account for different maneuver angles. The propellant consumption must be decreased by 10 percent for a 30-degree maneuver and increased by 20 percent for a 100-degree maneuver.

The manual single-axis maneuver propellant consumption is the same as the single-axis maneuver in paragraph 4.2.1.2.

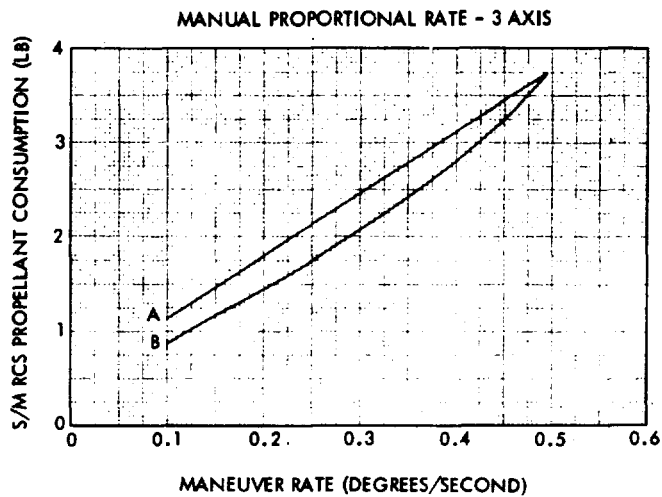
4.2.1.2 Automatic Attitude Control Maneuvers and Attitude Hold.

S/M RCS propellant consumption rates for G&N control maneuvers (attitude control and attitude hold), versus S/C

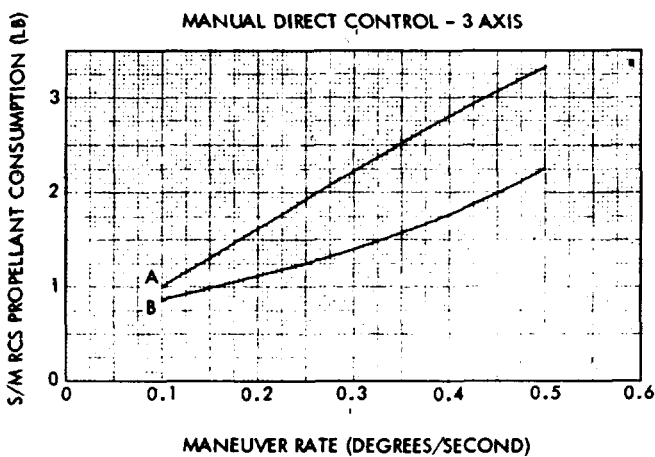
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CURVE	WEIGHT (LB)	INERTIA (SLUG-Feet Squared)		
		I <sub>XX</sub>	I <sub>YY</sub>	I <sub>ZZ</sub>
A	29,500	15,800	53,500	54,000
B	22,300	12,600	40,000	38,700



NOTE: WEIGHTS AND INERTIAS FOR CURVES A AND B ARE SAME AS SHOWN ON UPPER CHART.

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Figure 4-13. S/M RCS Propellant Consumption During Manual Attitude Control Maneuvers

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weight, are presented in figure 4-14. The same assumptions in paragraph 4.2.1.1 also apply to figure 4-14, in addition to the following:

- Non-maneuvered axes are held with a narrow deadband of  $\pm 0.2$  degree while the other axes are moved.
- A specific impulse ( $I_{sp}$ ) for a single jet RCS firing per axis that equals 180 seconds.
- A maneuver rate of 0.5 degree per second.

The S/M RCS propellant consumption rates for the attitude thermal (barbecue) control mode versus S/C weight are presented in figure 4-15. Applicable additional assumptions are as follows:

- Attitude hold in pitch and yaw are at a deadband of  $\pm 4.2$  degrees.
- Roll axis spin is 0.5 degree per second.

The S/M RCS propellant consumption required to damp free drift rates (caused by dynamic disturbances) versus time in free drift are presented in figure 4-16.

4.2.1.3 Translation Maneuvers.

S/M RCS propellant consumption required for settling SPS propellants versus S/C weight, for three configurations of RCS engine utilization, is presented in the upper chart of figure 4-17. The lower chart shows propellant required for RCS +X axis delta velocity maneuvers. Assumptions applicable to both charts in figure 4-17 are as follows:

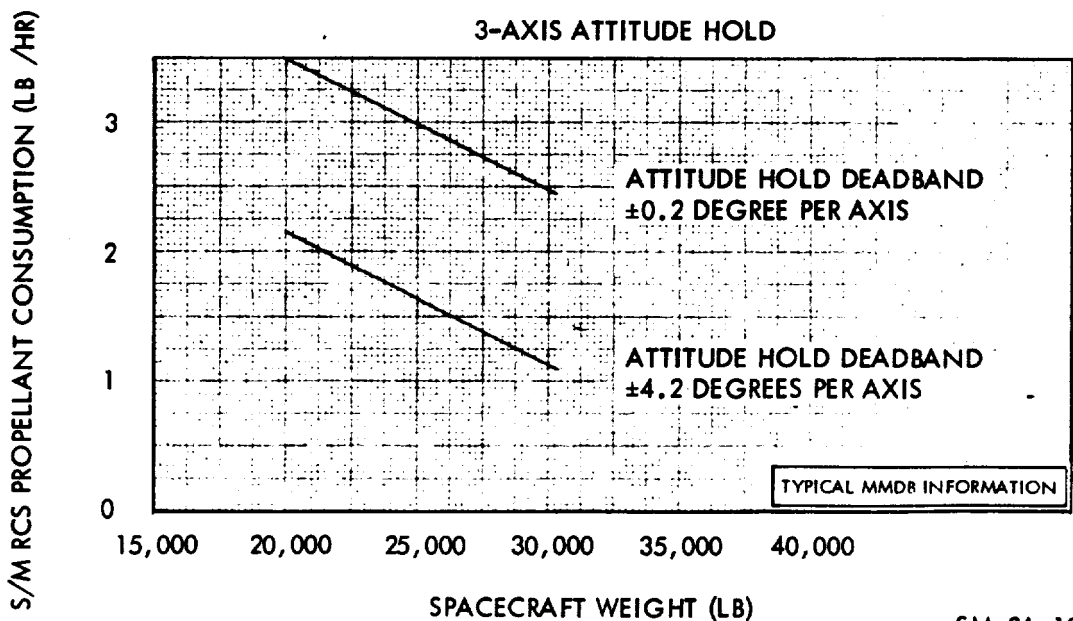
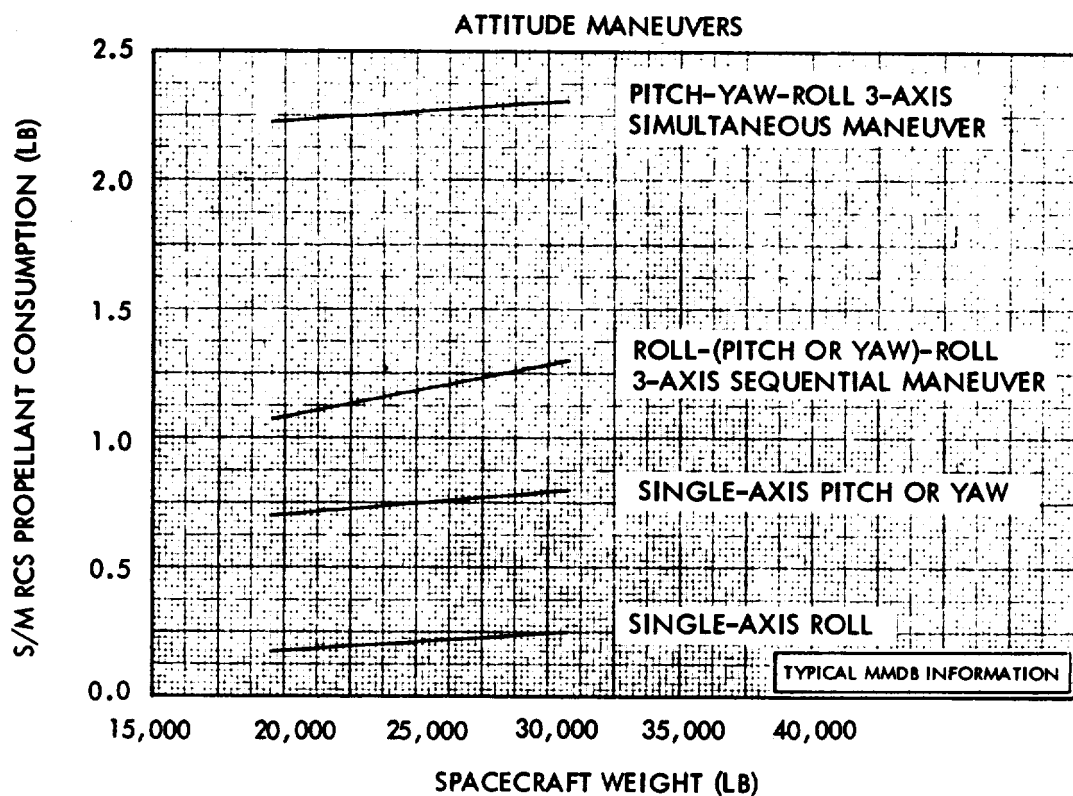
- The RCS engine thrust equals 100 pounds.
- $I_{sp}$  at attitude correction equals 185 seconds.
- $I_{sp}$  at translation equals 278 seconds.
- Dynamic disturbances (stated in paragraph 4.2.1.1) are neglected.
- Roll control propellant requirements are neglected.

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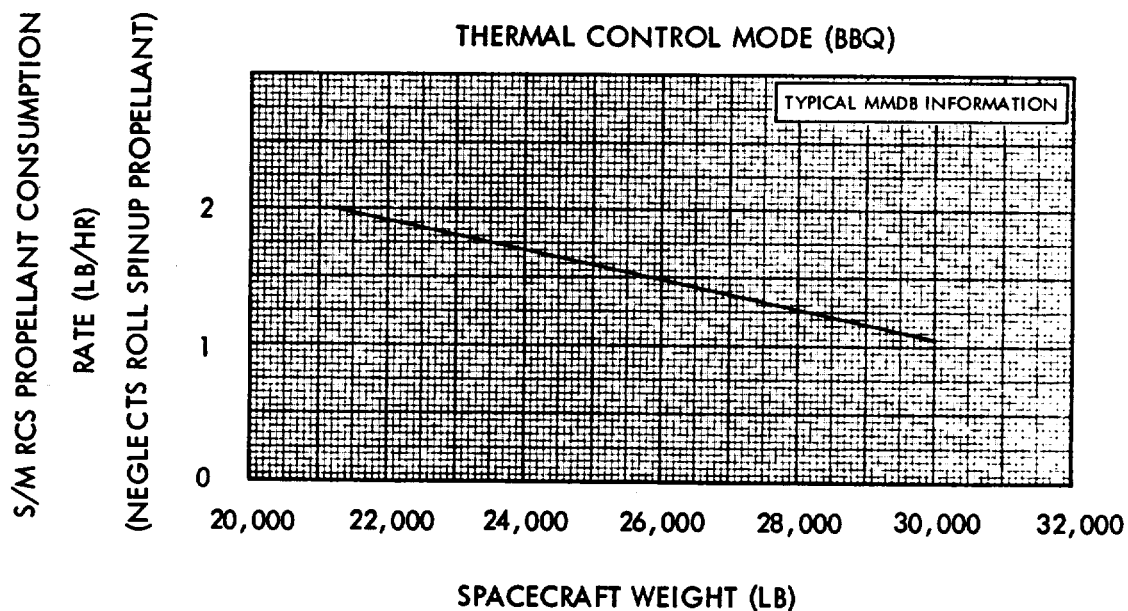
Figure 4-14. S/M RCS Propellant Consumption During Attitude Control Maneuvers and Attitude Hold

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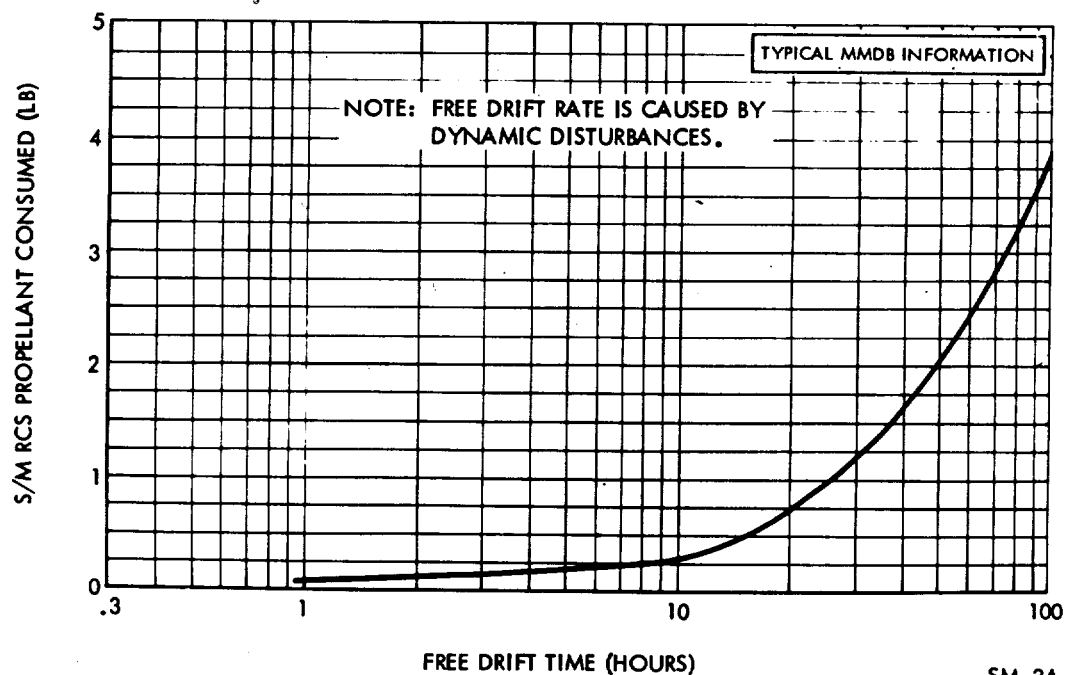
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Figure 4-15. S/M RCS Propellant Consumption for Thermal Control Modes



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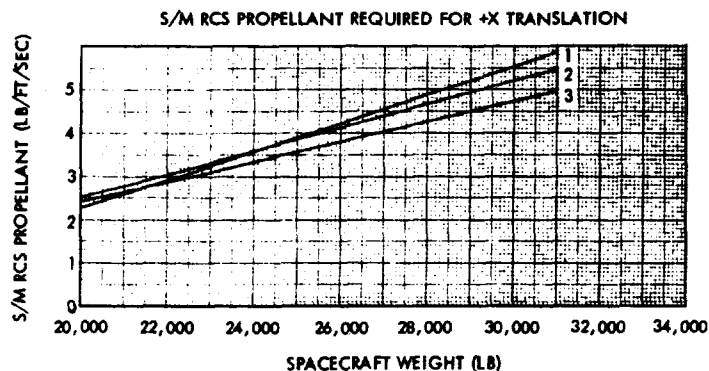
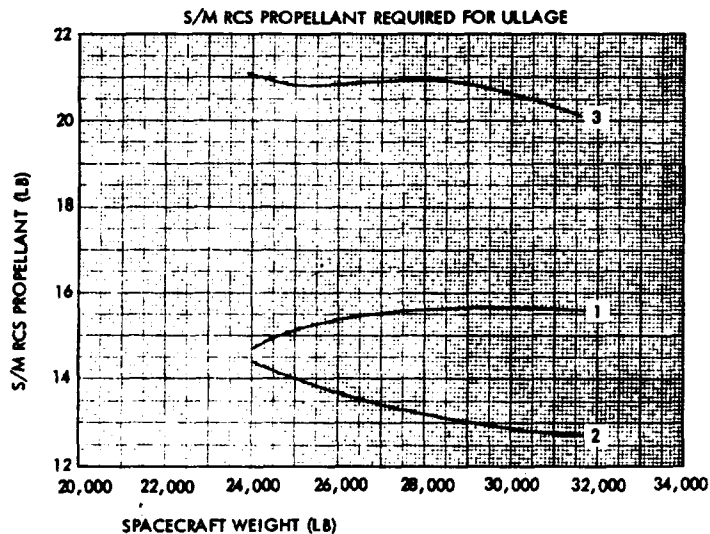
Figure 4-16. S/M RCS Propellant Consumption for Damping Out Free Drift Rate

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CONFIGURATION	AXIS	S/M RCS ENGINES			
		DISABLED	USED FOR		
			ATTITUDE CONTROL		PLUS X TRANSLATION
ONE	PITCH	3 & 4	1	2	2 & 1
	YAW	6 & 5	7	8	NONE
TWO	PITCH	2 & 1	3	4	NONE
	YAW	7 & 8	5	6	6 & 5
THREE	PITCH	NONE	3 & 1	2 & 4	2 & 1
	YAW	NONE	7 & 5	6 & 8	6 & 5



NOTE:

Curves 1, 2, and 3  
represent same engine  
configuration as above.

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Figure 4-17. S/M RCS Propellant Consumption for SPS Propellant Settling and Translation Maneuvers

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4.2.1.4 Attitude Hold Following SPS Burn.

S/M RCS propellant consumption required for attitude hold in three axes, immediately following an SPS burn and extending over a 10-minute period after the SPS burn, is presented in the upper chart of figure 4-18. (This curve includes the total RCS requirement and should not be added to the results obtained from figure 4-14. However, after the end of the 10-minute slosh damping period, the rates in the lower chart of figure 4-14 should be used.) For attitude holds delayed after the termination of an SPS burn, both charts in figure 4-18 are used for adjusting RCS propellant consumption rates.

4.2.2 C/M RCS PROPELLANT CONSUMPTION DATA.

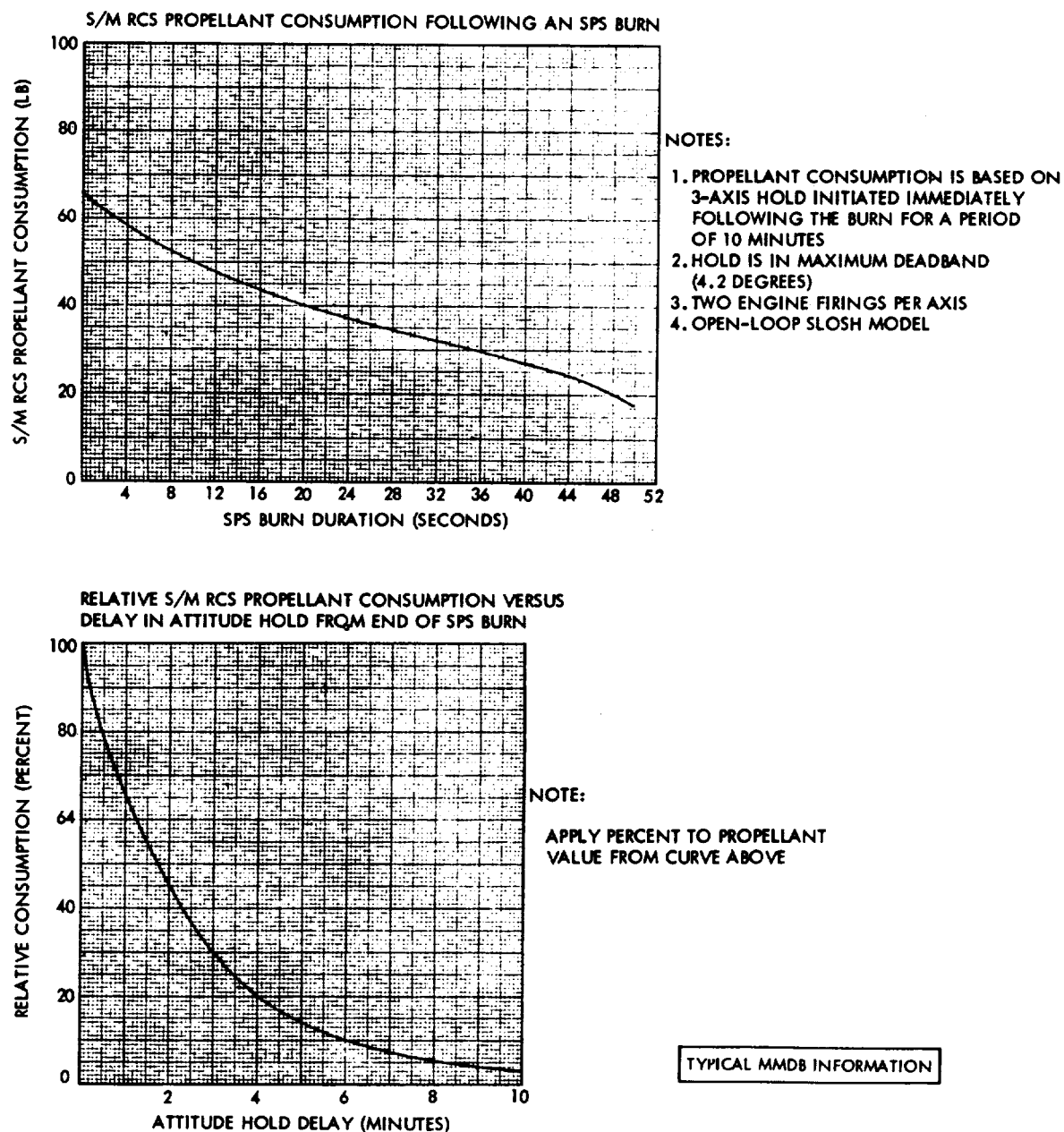
Propellant consumables utilized by the 12 C/M RCS engines provide thrust for three-axes rotational and attitude control of the C/M (after an abort or during normal entry). The oxidizer/fuel ratio (by weight) for each of the four roll engines is  $2.1 \pm 0.09:1$  at a propellant consumption rate of 0.345 lb/sec. The oxidizer/fuel ratio (by weight) for each of the eight remaining engines is  $2.0 \pm 0.09:1$  at a propellant consumption rate of 0.342 lb/sec. Any remaining propellant, including the helium used as a pressurant, is ejected prior to C/M touchdown (for all mission modes). Nominal values for the individual C/M RCS consumables (usable tank capacity of 225 pounds) are as follows:

Weight per Tank				
Consumables	Storage Tank	Filled (lb)	Usable (lb)	Delivery Rate to Engine
Nitrogen tetroxide (N <sub>2</sub> O <sub>4</sub> ) (oxidizer)	2	89.2	75.0	0.228 lb/sec (oxidizer/fuel ratio of 2:1)
				0.234 lb/sec (oxidizer/fuel ratio of 2.1:1)
Monomethylhydrazine (MMH) (fuel)	2	45.2	37.5	0.114 lb/sec (oxidizer/fuel ratio of 2:1)
				0.111 lb/sec (oxidizer/fuel ratio of 2.1:1)
Helium (He) (pressurant)	2	0.52	0.52	N/A

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Figure 4-18. S/M RCS Attitude Hold Propellant Consumption Following SPS Burn

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Representative C/M RCS propellant consumption time histories are presented in figure 4-19 for nominal and off-nominal single-system RCS entries. The curves include pre-entry propellant expended (5 pounds for nominal and 9 pounds for off-nominal rates).

4.2.3 SPS PROPELLANT CONSUMPTION DATA.

Propellant consumables utilized by the SPS engine (at 69.09 lb/sec) provide thrust for significant spacecraft velocity changes after booster separation. Nominal values for the SPS consumables are as follows:

Consumables	Storage (and Sump) Tank	Weight per Tank		Delivery Rate to Engine
		Filled (lb)	Usable (lb)	
Nitrogen tetroxide ( $N_2O_4$ ) (oxidizer)	1	30,600	27,333	46.06 lb/sec
50% unsymmetrical dimethylhydrazine (UDMH/ $N_2H_4$ ) (fuel)	1	15,300	13,677	23.03 lb/sec
Helium (He) (pressurant)	2	48.2	48.2	N/A

NOTE Storage tanks for the SPS fuel and oxidizer also include a sump tank. S/C 012 will not be scheduled to carry the possible total propellant load of about 45,900 pounds.

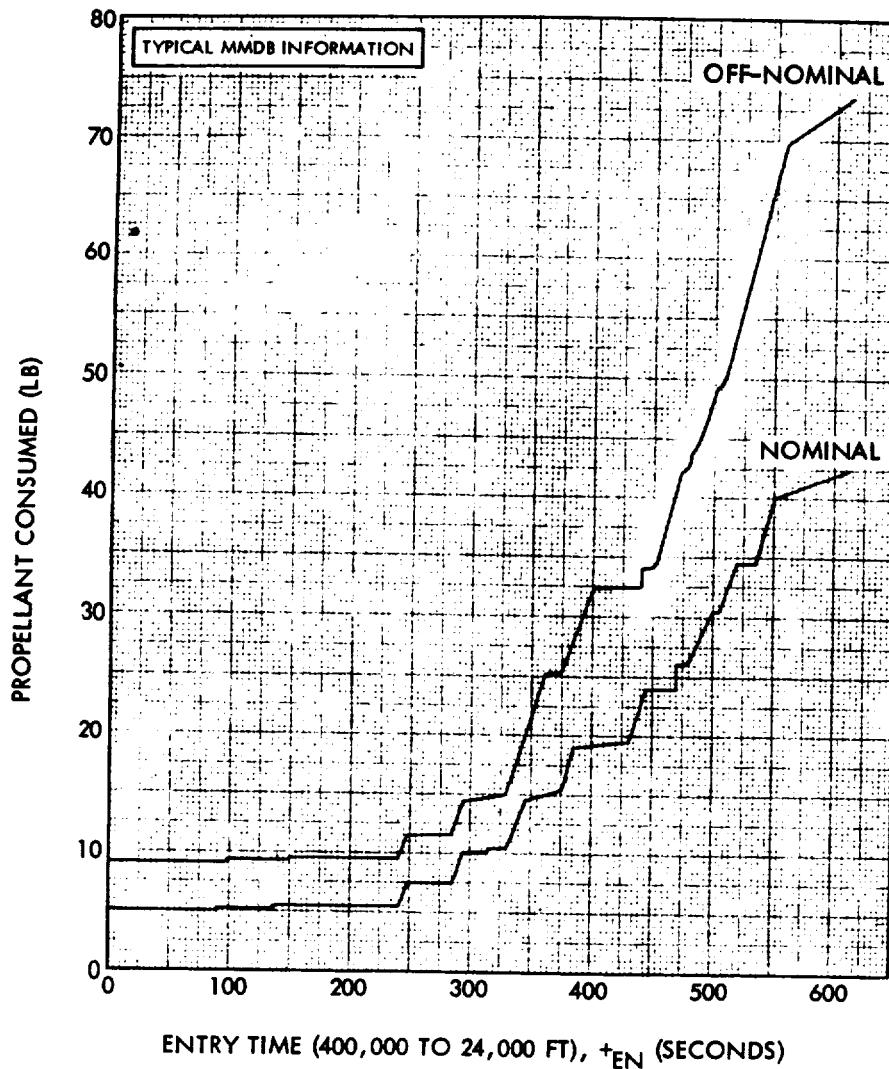
Spacecraft weight is plotted against characteristic velocity for nominal and minimum values of specific impulse. (See figure 4-20.) A sample path traces a typical solution for propellant weight when initial weight, specific impulse, and characteristic velocity change are given. Arrows on the chart, starting with an initial value for weight ( $W_1$ ) indicate the direction of flow for the sample problem. It is important to note that the characteristic velocity ( $V_c$ ) scale does not represent values of  $\Delta V$  remaining aboard the S/C, but is intended to serve as a reference only on which increments ( $\Delta V_c$ ) may be taken as shown in the sample.

In order to account for a 4500 pound-seconds loss for each SPS engine start, 14.5 pounds of propellant must be added to the

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	NOMINAL	OFF-NOMINAL
$V_g$	24,216 FPS	24,216 FPS
$\gamma_g$	-1.65 DEG	-1.65 DEG
$\alpha$	156 DEG	156 DEG
$\beta$	0 DEG	0 DEG
$\phi_{EN}$	0 DEG	0 DEG
$Cl_0$	-0.0004 DEG	-0.00006
GUST	NONE	HALF SINE WAVE
$\sigma$	52.7 DEG	52.7 DEG
RANGE	1547 NM	1547 NM

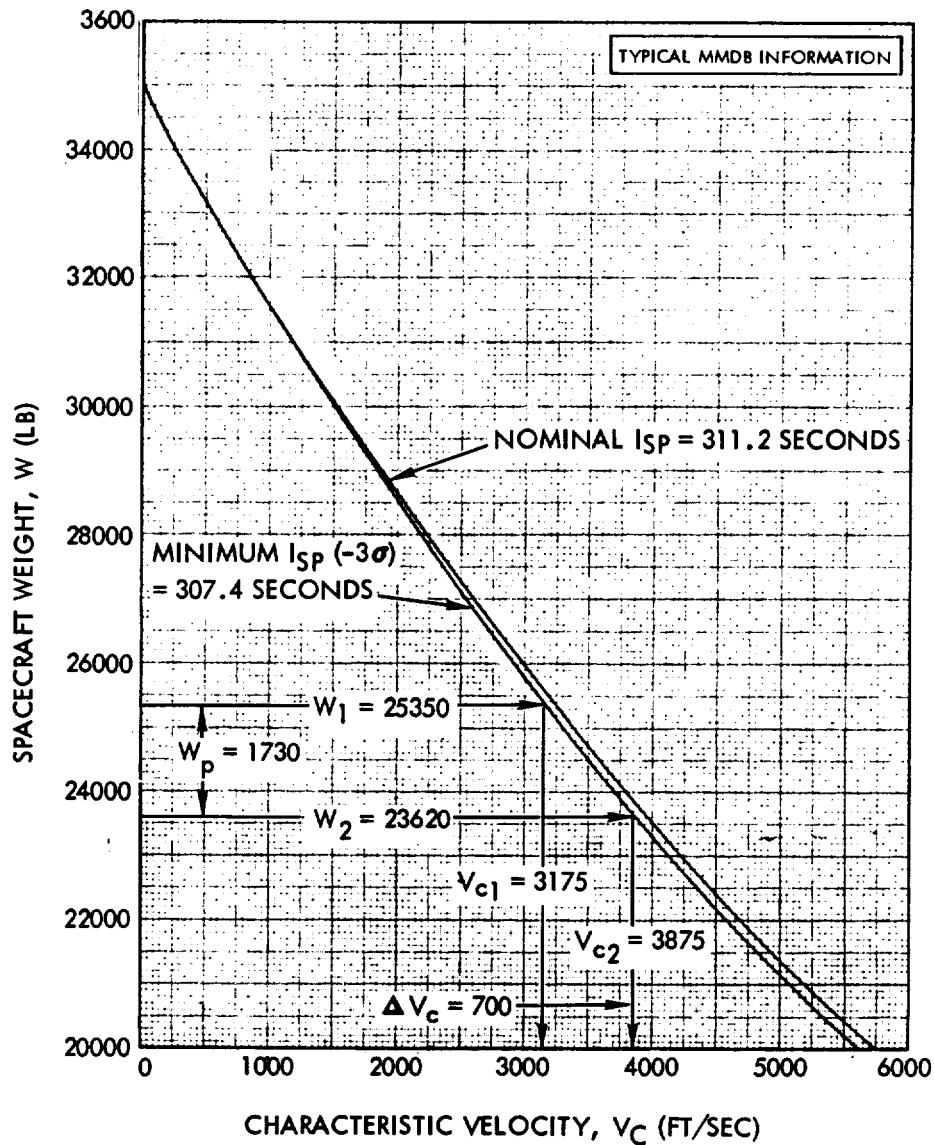
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Figure 4-19. C/M RCS Propellant Consumption  
Time Histories - Single System

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GIVEN: INITIAL SPACECRAFT WEIGHT, W<sub>1</sub>  
SPECIFIC IMPULSE, I<sub>SP</sub>  
CHARACTERISTIC VELOCITY  
CHANGE, ΔV<sub>C</sub>  
g = 32.174 FT/SEC<sup>2</sup>

$$\text{PROPELLANT WEIGHT, } W_p = W_1 \left[ 1 - \frac{1}{e^{\left( \frac{\Delta V_c}{g I_{SP}} \right)}} \right]$$

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Figure 4-20. SPS Propellant Consumption

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propellant consumption noted during each firing. (The total propellant requirements are limited to the total usable propellants available to the S/C.)

4.2.4 EPS AND ECS CONSUMPTION DATA.

Oxygen and hydrogen reactants (from the cryogenic storage system) are consumed by the EPS fuel cell power plants in the generation of electrical power for the S/C. Water, as a byproduct, is provided for the ECS. Oxygen from the cryogenic storage system is also supplied to the ECS for metabolic consumption by the crewmembers and for pressurization of the crew compartment and the PGA. The cryogenic tanks for oxygen and hydrogen are initially filled to at least 97 percent of full capacity. Nominal values for these consumables are as follows:

Consumables	Storage Tank	Weight per Tank		Flow Rate to System
		Filled (lb)	Usable (lb)	
Hydrogen (H <sub>2</sub> ) (supercritical gas)	2	29.0	28.0	0.14 lb/hr (min) 0.27 lb/hr (max) (0.75 lb/hr-purge only)
Oxygen (O <sub>2</sub> ) (supercritical gas)	2	327.0	320.0	1.70 lb/hr (min) 2.58 lb/hr (max) (0.6 lb/hr-purge only)
Nitrogen (N <sub>2</sub> ) (fuel cell reference pressure)	3	0.44	0.44	N/A

NOTE Both the EPS and ECS utilize oxygen from the same cryogenic storage system (489 pounds of usable O<sub>2</sub> for the EPS and 151 pounds for the ECS).

4.2.4.1 EPS Fuel Cell Reactants Consumption.

The O<sub>2</sub> and H<sub>2</sub> consumption versus electrical output for one, two, or three fuel cell power plants is shown in figure 4-21. Only the H<sub>2</sub> curve is given. (The O<sub>2</sub> consumption rate is eight times the H<sub>2</sub> rate.) Water generated by the fuel cells may be calculated by multiplying the H<sub>2</sub> consumption rate by nine.

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NOTE:  
WATER GENERATION RATE IS  
OBTAINED BY MULTIPLYING H<sub>2</sub>  
CONSUMPTION RATE BY NINE

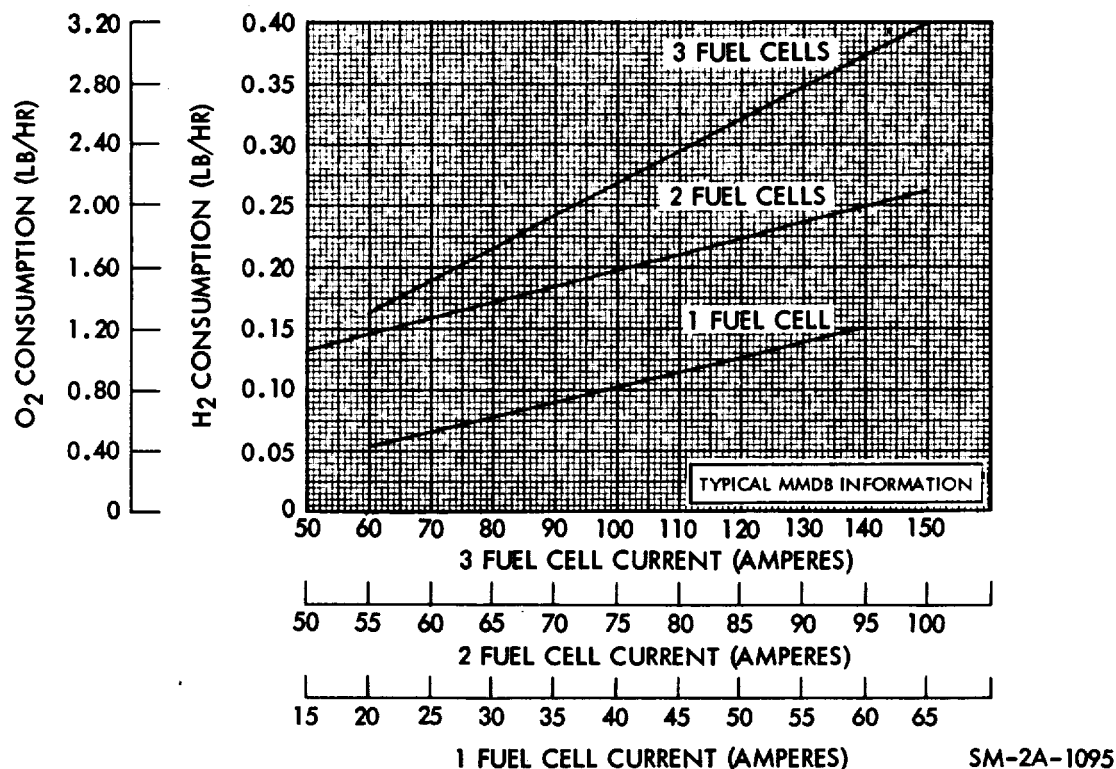


Figure 4-21. Cryogenic Consumption Versus Fuel Cell Current

In order to maintain fuel cell operating efficiency, purging of each power plant is accomplished every 7 hours. The purges will normally be staggered so that a H<sub>2</sub> purge will follow an O<sub>2</sub> purge by 3.5 hours. The present purging cycle of 7 hours is based upon the maximum normal power output of 1420 watts per fuel cell. The time between purges is based upon the ratio of the present maximum of 1420 watts/fuel cell power plant to the actual maximum gross power demand times 7 hours. Thus, if the actual maximum gross power demand is 710 watts/fuel cell module, the nominal purge interval of 7 hours would be increased by 1420/710 or 2. Multiplying 2 times 7 would then provide a purge interval of 14 hours. During purging, the power plant continues to consume reactants in the quantities required to produce the power demanded by S/C electrical loads. The duration of each H<sub>2</sub> purge is 80 seconds and 120 seconds for each O<sub>2</sub> purge.

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4.2.4.2 EPS Electrical Power Output.

During a normal mission, from launch until entry, about 618 kwh of electrical power is supplied to the S/C by three fuel cell power plants operating in parallel. If one power plant should fail, the remaining two will provide for normal power loads. In the event two power plants fail, S/C emergency loads can be accommodated. The three batteries, normally reserved for entry and postlanding phases of the mission, can be utilized to provide for peak loads above operating fuel cell capacities.

NOTE The EPS requires a minimum steady-rate power level of 1689 watts with three fuel cells operating or 1550 watts with two fuel cells operating during orbit. However, a minimum transient power level of 1500 watts for three fuel cells can be reached without causing an overvoltage in the EPS. (Tests are being conducted to determine if a minimum transient power level of 1200 watts for three fuel cells is feasible.)

- By drawing on battery power and recharging, an additional 1.0 kwh of energy can be obtained for use during orbital flight.
- The S/C is capable of sustaining an emergency power load of 1200 watts with one fuel cell operating during orbit.

4.2.4.3 ECS Oxygen and Water Consumption.

Oxygen and water consumables are utilized by the ECS in providing for needs peculiar to the presence of men aboard the spacecraft. Nominal values for the ECS consumables are as follows:

Consumables	Source	Usable Weight (lb)	Remarks
Oxygen (O <sub>2</sub> )	Cryogenic storage system tanks (2).  NOTE The cryogenic storage system supplies O <sub>2</sub> to both the ECS and EPS (151 pounds for the ECS and 489 pounds for the EPS).	151.0	The basic purpose of the ECS oxygen is for crew metabolic consumption and control of the C/M pressure as follows:  a. Metabolic - three men at 0.075 lb/hr/man or 0.225 lb/hr total  b. C/M leakage - 0.2 lb/hr

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Consumables	Source	Usable Weight (lb)	Remarks
Potable water	Surge tank	3.7	c. 2 C/M repressurizations - 11.7 lb (5.85 lb/ea). Initially filled during ground service
	Entry tank	1.0	Initially filled during ground service
	One C/M potable water supply tank	36.0	Initially filled during ground service; the tank is replenished during flight by the EPS fuel cell power plants at a nominal rate of 0.77 lb per kilowatt. If tank is full, water will overflow into C/M waste water tank.
Waste water	One C/M waste water supply tank	56.0	Initially filled during ground service and then by overflow of water from potable water tank.
	Two S/M water supply tanks	112.0	Additional supply of water is carried in S/M to replenish C/M water tanks, if necessary.
Nitrogen (N <sub>2</sub> ) (pressurant)	One N <sub>2</sub> supply tank	1.5	Used to pressurize the S/M water supply tanks.

NOTE The ECS potable water will be primarily used for metabolic purposes by the crew and not for cooling purposes in the S/C (unless waste water becomes depleted).

- The ECS radiator inlet temperature is affected by heat transfer from EPS components. As the components become warmer from increased electrical loads, a greater rate of heat transfer will take place. ECS radiator freezing may result if both radiators are exposed to deep space for more than 1 hour and the inlet temperature is below 75°F

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with an electrical current level of about 55 amps. By rolling or tumbling the S/C, to allow for periodic exposure of the radiators to the sun, the inlet temperature can be 70°F with an electrical current level of about 50 amps before the space radiators start to freeze.

4.3 RCS AND SPS THRUSTING DATA.

4.3.1 RCS TRANSLATION CONTROL.

Spacecraft translation is possible at any time after S-IVB separation and prior to the time when S/M-C/M separation occurs. Translation maneuvers are provided through the S/M RCS engines and are normally initiated manually by the translation control T-handle in the  $\pm X$ , Y, and Z axes, or by the DIRECT ULLAGE switch in the  $+X$  axis. The translation control (manipulated in the counterclockwise position to the abort detent for about 2.5 seconds) also provides for CSM/S-IVB separation. While the control is in the abort detent position, the CSM attitude is not controlled. Upon confirmation of physical separation, the translation control is moved to the  $+X$  position and the SCS initiates attitude control to a maximum deadband of 5 degrees. (Refer to section 2 for systems operation.)

NOTE Each S/M RCS engine nominally develops 100 pounds of thrust. If four engines are ignited (as in a  $\pm X$  translation), the S/C will accelerate at 0.4 to 0.8 ft/sec<sup>2</sup>, depending on the S/C weight and control mode. (Only two engines are ignited for  $\pm Y$  and  $\pm Z$  translations.)

- The minimum RCS impulse duration, assuming average human response, is on the order of 200 milliseconds. The maximum translation duration is a function of the available propellant.

4.3.2 RCS ROTATION CONTROL.

Automatic or manual rotational control of the S/C is provided in both the G&N and the SCS control modes. (Refer to section 2 for systems operation.)

NOTE The S/C can have a maximum angular acceleration from 1.0 to 1.5 degrees per second<sup>2</sup>, depending on the S/C mass configuration and RCS engines fired.)

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4.3.2.1 G&N Attitude Control.

During the G&N attitude control mode, the inertial measurement unit (IMU) maintains the primary inertial attitude reference for the S/C. Rotation changes are commanded by either the Apollo guidance computer (AGC) when verb 70 is entered in the S/C display keyboard (DSKY) for manual maneuvers with the rotation control, or by manually dialing the coupling display units (CDU) for maneuvers preprogrammed in the AGC.

NOTE The AGC can be programmed to command a three-axis 60-degree reorientation of the S/C (and is similar in operation to an attitude orientation maneuver for an IMU alignment).

- All preprogrammed AGC maneuvers are executed at an attitude rate of 0.5 degree per second (4.0 degrees per second for abort or entry maneuvers only). In the G&N mode, a  $\pm 4.2$  degree maximum or a  $\pm 0.2$  degree minimum attitude error deadband is available. The S/C will have a limit cycle rate of less than 0.2 degree per second within these deadbands.
- G&N attitude maneuver rates (used for IMU fine alignments and checks) are limited by the G&N digital program to 0.5 degree per second in pitch, roll, and yaw.

4.3.2.2 SCS Attitude Control.

During the SCS attitude control mode, the body mounted attitude gyros (BMAG) provide an automatic reference for holding the S/C at a specific attitude within a  $\pm 4.2$  degrees maximum or a  $\pm 0.2$  degree minimum attitude error deadband. If the S/C is then maneuvered manually by the rotation control, the attitude gyro coupling unit (AGCU) will automatically cage the attitude gyros, correct the attitude hold reference, and present a new display on the FDAI when the maneuver is completed.

4.3.2.3 Manual Attitude Control.

Manual maneuvers for attitude control of the S/C are provided by use of the rotation control for direct and proportional rates, and by the attitude impulse control for low-rotational rates (minimum impulse). The primary

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purpose of the manual attitude controls and pertinent data are as follows:

1. Direct rotation control, for emergency and backup conditions, is commanded by use of the rotation control (stick) about the desired axes to its hard stops. Just before engaging the hardstops, a switch closes and applies a direct command to the RCS direct coils. Rate feedback is not used to cancel the stick movement, but the BMAG-AGCU loop is closed and maintains an attitude reference to its limits.

NOTE The attitude rate, commanded by direct rotation, is limited only by human endurance and the RCS propellant supply. Start and stop transients depend on pilot technique and the attitude reference (FDAI or visual landmark) used to close the outer control loop. The inertial references start to accumulate error (due to gyro slue rate limitations) at a rate of 20 degrees per second about the roll axis and 5.0 degrees per second about the pitch or yaw axis.

2. Proportional rotation control, for attitude corrections, is commanded by displacement of the manual S/C rotation control (stick) into a desired proportional rate (when referring to S/C attitude display on the FDAI).

NOTE The resulting proportional rate will vary from a minimum of 0.2 degree per second to a maximum of 0.65 degree per second (depending on stick displacement). Attitude error deadbands are  $\pm 4.2$  degrees maximum and  $\pm 0.2$  degree minimum.

3. Attitude impulse control, for commanding low-rotational rates about all three axes, is available in either G&N or SCS modes of operation and is used as required during navigational sighting periods. This is accomplished through the attitude impulse control located on panel 105.

NOTE After the attitude impulse control is enabled and displaced, a switch closure in the control unit will cause one pulse of  $18 \pm 4$  milliseconds, which is applied to the RCS jet selection logic. (One pulse is generated for each attitude impulse switch closure.)

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- Attitude impulse control is not a proportional control and does not provide for attitude hold. When this control is enabled, relay action removes all rate attitude error and control inputs from the SCS electronics.
  - Use of minimum impulse (for fine adjustment of S/C attitude) excites rates of about 0.01 degree per second minimum to 0.5 degree per second maximum.

4.3.3 SPS ENGINE THRUST PERFORMANCE.

4.3.3.1 SPS Small-Impulse Operation.

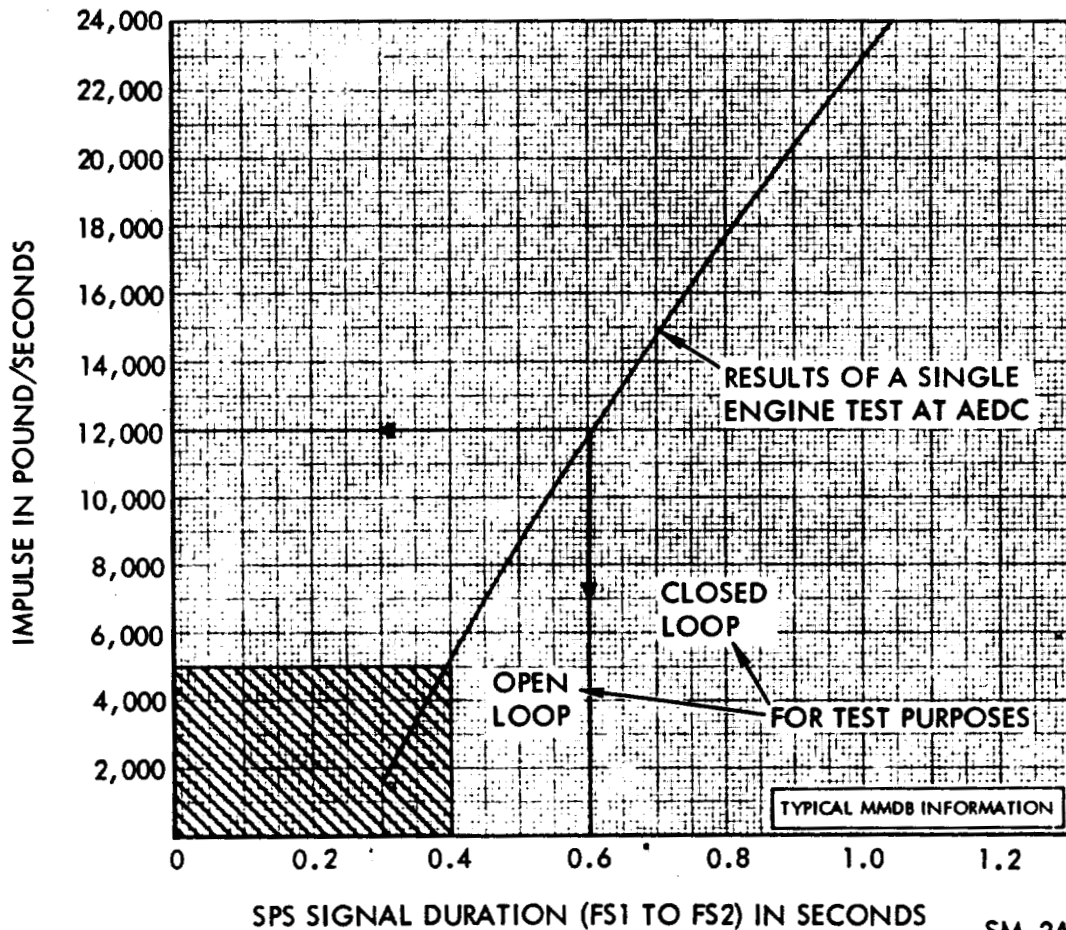
The SPS engine is capable of accepting a shutdown signal at any time after receipt of a start signal. A nominal minimum impulse bit of 12,000 pound-seconds is developed when the engine is fired for an open-loop operation period of 0.6 seconds. (See figure 4-22.) The run-to-run minimum impulse-bit tolerance is  $\pm 300$  pound-seconds (1 sigma). Impulse value as a function of start-to-shutdown signal duration (FS1 to FS2), is estimated from qualification tests generated at AEDC (Arnold Engineering Development Center). (Propellant consumption for small impulse firings including the 14.4-pound propellant loss for each SPS engine start is covered by the equation  $W_p = (\text{Impulse} + 4500)/I_{sp}$ ).

4.3.3.2 SPS Engine Start and Shutdown Transients.

The SPS engine start and shutdown transients are presented in figure 4-23. Curves show the percentage of rated thrust as a function of elapsed time from start (FS1) and shutdown (FS2) command signals. Rated thrust is based on nominal inlet condition. All data estimates are from AEDC qualification tests. The start transient total impulse from FS1 to 90-percent rated thrust is limited to the range from 100 pound-seconds (minimum) to 400 pound-seconds (maximum). The run-to-run tolerance on start transient impulse is  $\pm 100$  pound-seconds (1 sigma). The shutdown impulse from FS2 to 10-percent rated thrust is limited to a range from 8000 pound-seconds (minimum) to 12,000 pound-seconds (maximum). The run-to-run tolerance on the shutdown impulse is  $\pm 300$  pound-seconds (1 sigma).

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Figure 4-22. SPS Small Impulse Firings for Open-Loop Operations

4.3.3.3 SPS Delta V Capability.

The SPS delta V capability remaining versus SPS propellant remaining is presented in figure 4-24.

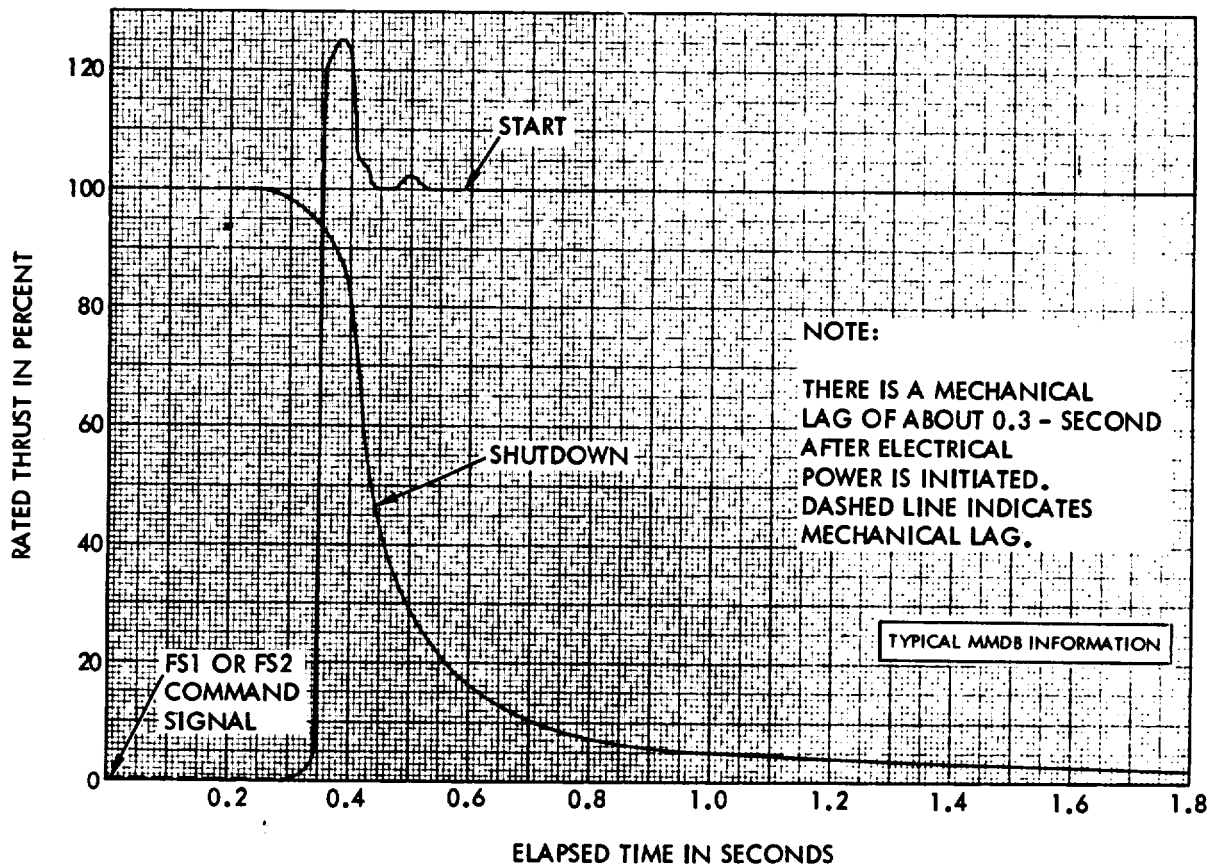
4.3.3.4 SPS Engine Gimbal Angle Determinations.

The engine gimbal angle determinations for an SPS firing (thrust vector through center of gravity) can be calculated during



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Figure 4 -23. SPS Engine Start and Shutdown Transients

flight by the amount of SPS fuel remaining aboard the spacecraft. (See figure 4-25.) The ground controller will determine SPS engine gimbal angles if propellant leaks and/or other than nominal oxidizer to fuel ratios occur.

4.4 S/C OPERATIONAL CONSTRAINTS AND LIMITATIONS.

4.4.1 OPERATIONAL CONSTRAINTS.

Attitude constraints are necessary to prevent excessive exposure of certain spacecraft surface features to solar heating, earth albedo, or deep space. These constraints are required to control temperatures for the ECS radiator inlet, S/M RCS engines, SPS propellant feedlines, and the heat shield.

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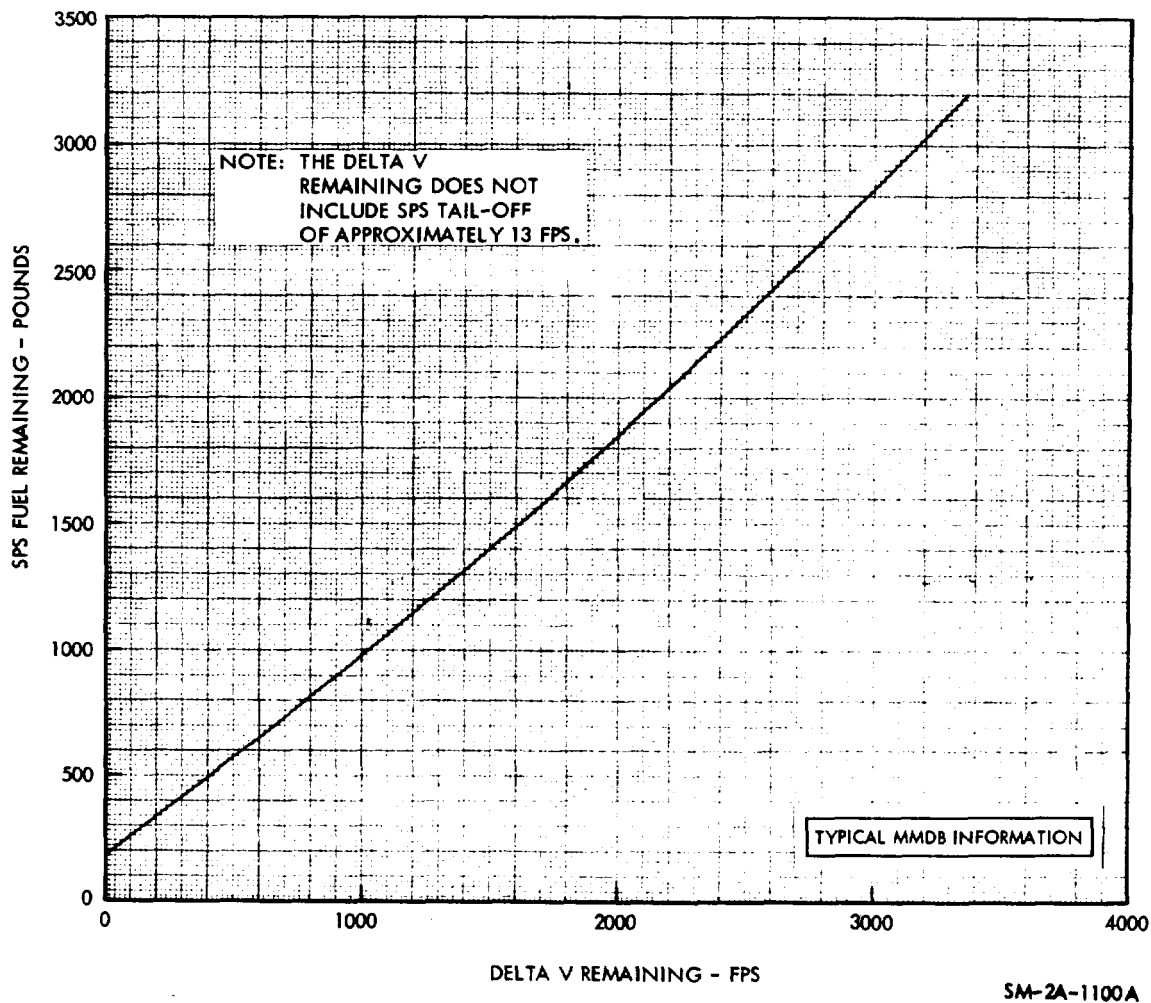
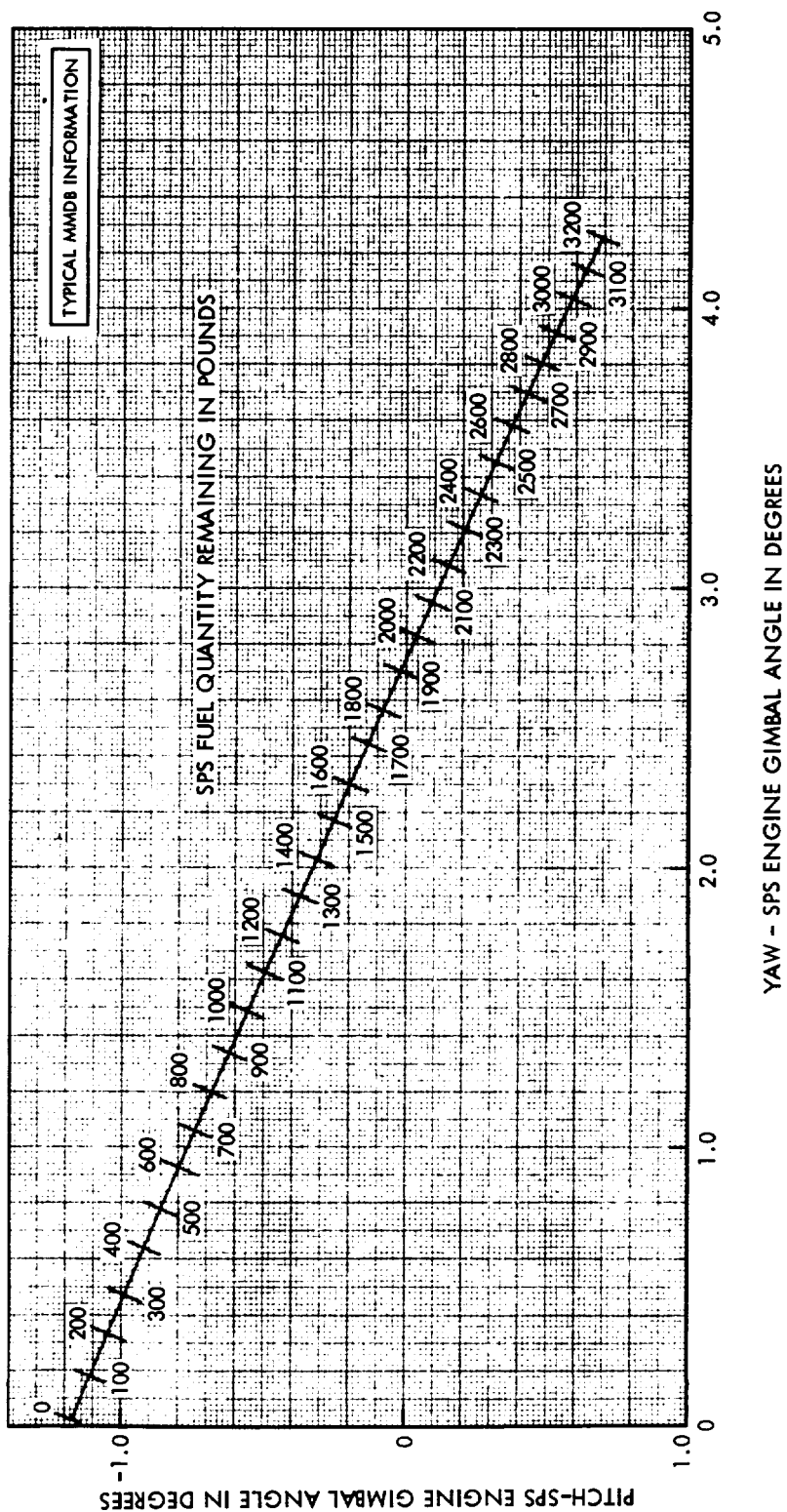


Figure 4-24. SPS Delta V Remaining Versus Propellant Remaining

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Figure 4-25. SPS Engine Gimbal Angle Settings

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4.4.1.1 ECS Radiator Inlet Temperature.

The ECS radiator inlet temperature (obtained from MSFN or the auxiliary DC volts meter on panel 200) should be maintained at 75°F or warmer to prevent against radiator freezing. However, excessive water boiling will result if the radiators are directly exposed to the sun for prolonged periods. S/C orientations exposing the ECS radiator surface to solar incidence angles less than 45 degrees should not be maintained longer than 20 minutes per orbit. Also, the S/C attitude should be constrained inertially or held fixed relative to the earth without roll for a period longer than one orbit, if the solar incidence to the radiator is less than 45 degrees. To prevent excessive water consumption (boiling) the S/C attitude must not be constrained in an inertial or earth-fixed orientation without roll for longer than 3 hours.

CAUTION                      Extreme radiator sooting can be detected  
by a rapid depletion of the water supply  
and high radiator outlet temperature.

- If the radiator outlet temperature averages above 53°F as a result of extreme sooting, high electrical loads, or poor radiator orientation, the water tanks will be depleted at a rate incompatible with the planned mission duration time.

NOTE      Observance of ECS radiator constraints will also ensure a satisfactory environment for EPS radiator operation.

4.4.1.2 S/M RCS Engine Temperatures.

The S/M RCS engines are qualified to work within the range of 35° to 175°F, the propellant valve temperature limits. A red warning light on panel 10 will illuminate to indicate when the temperatures exceed this range. Temperatures above 175°F are not expected, except temporarily (possible) during boost. Heaters that cycle automatically are provided on each quad to maintain temperatures above the lower limit. However, if one quad is continuously pointed away from the sun for longer than 10 hours, it is possible for the 40°F lower temperature limit (for the propellant) to be reached at the RCS tank outlet.

NOTE      S/C attitude should be monitored during extended periods between RCS firings to ensure that safe temperatures are maintained.

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4.4.1.3     SPS Propellant Feedline Temperatures.

SPS propellant feedlines are normally maintained above 40°F by heaters and insulation. The MSFN should monitor SPS external line temperatures and advise the crew whenever temperatures drop below 50°F. If S/C attitude is maintained so that the SPS is pointed away from the sun for an extended period and heater capacity is insufficient to maintain line temperatures above 40°F, the S/C should be reoriented until acceptable SPS line temperatures are reached.

4.4.1.4     Heat Shield Temperature.

The heat shield ablator lower temperature limit of -150°F can be exceeded and cause surface cracking if the thin (-Z) portion of the ablator is pointed away from the sun for longer than 3 hours. Because of the moderate response time, it is unlikely that a critical cold condition would be approached during the mission.

CAUTION            If the heat shield ablator temperature is allowed to rise and remain above 200°F for any aggregate period longer than 2 hours, outgassing will result and cause a corresponding degradation to the ablator stress margin.

4.4.2        OPERATIONAL LIMITATIONS.

The available data in the subsequent paragraphs shows limitations imposed on the S/C and/or crew during ascent, descent or aborts, spaceflight, and entry.

4.4.2.1     Acoustic and Vibration Effects.

The crew will be exposed to acoustic and vibration effects during ascent (130 seconds), possible LES aborts (10 seconds), and entry (100 seconds). Vibration effects will also be experienced during high-altitude aborts (SPS induced) and spaceflight SPS firings. (See figures 4-26 and 4-27.)

4.4.2.2     Altimeter Error and C/M Base Pressure Effects.

The altimeter (barometric pressure indicator) error resulting from velocity pressures on the command module (below 14,000 feet) is shown in figure 4-28.

4.2.2.3     C/M Lift/Drag Profile and Entry Effects.

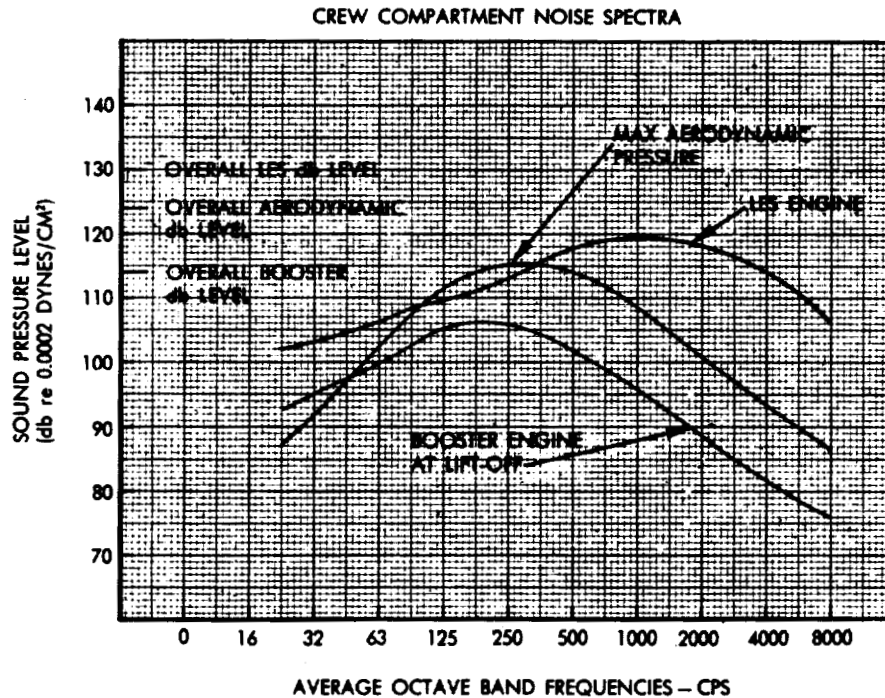
Charts showing the C/M lift/drag profile and time histories for normal entries are shown in figures 4-29 through 4-31.

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S/C OPERATIONAL CONSTRAINTS AND LIMITATIONS

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- 55 db = Sound pressure level (SPL) under average office conditions.  
79 db = Maximum SPL inside S/C during space flight with all equipment operating.

NOTES: 1. During space flight, C/M inside noise level is mainly due to equipment operation. SPS and RCS engine firings have little effect on the internal noise level.  
2. Each astronaut can reduce the crew compartment noise level about 15 db by utilizing his space suit and closing the helmet visor.

- 120 db = SPL where discomfort is experienced.  
140 db = SPL where pain is encountered.  
160 db = SPL where the human ear drum can be ruptured.  
200 db = SPL equivalent to a 50-pound TNT blast at 10 feet.

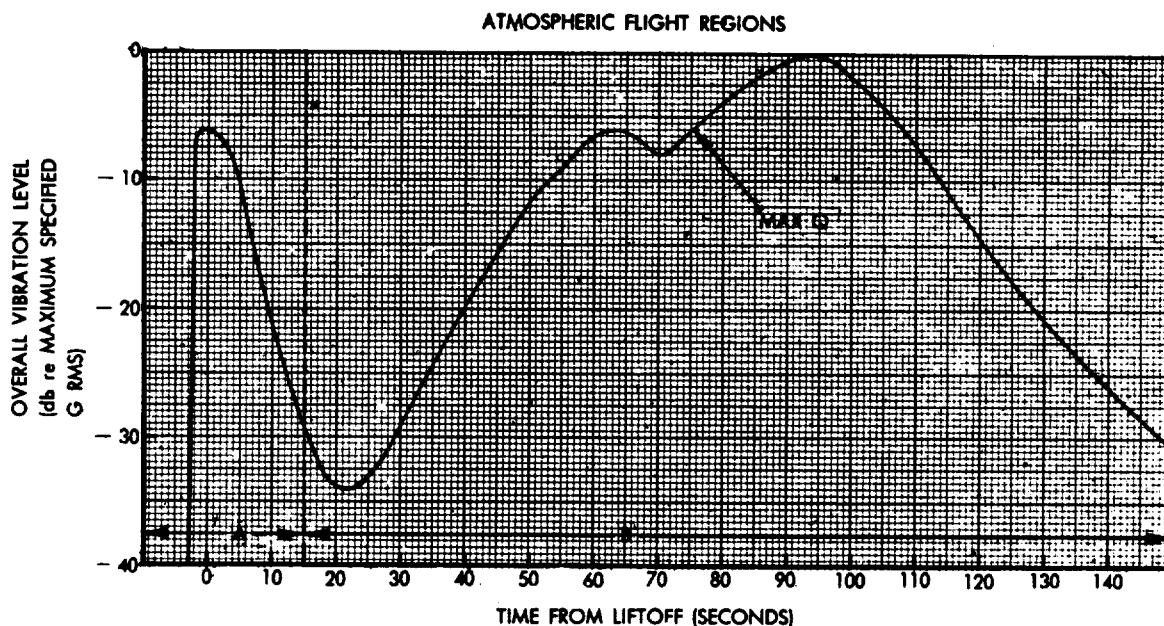
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Figure 4 -26. C/M Crew Compartment Acoustics

S/C OPERATIONAL CONSTRAINTS AND LIMITATIONS

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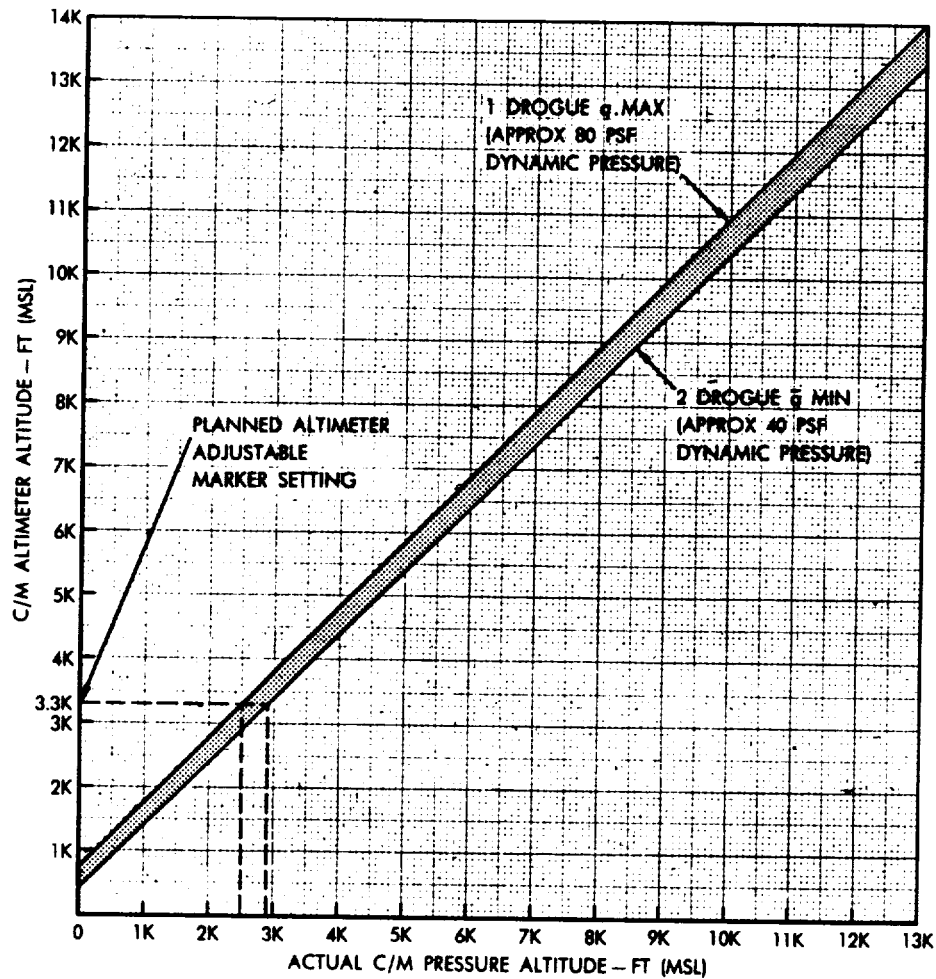
- NOTES: 1. Zero on the vertical scale indicates the maximum vibration experienced during flight. The vibration levels are based on boilerplate and spacecraft flight test measurements.
2. Letter "A" indicates vibration time induced by booster engine exhaust (influenced by the flame buckets) and noise reflected from the ground and launch pad.
3. Letter "B" indicates vibration induced by aerodynamic turbulence. As the launch vehicle velocity increases, pressure fluctuations in the turbulent boundary layer (and wake turbulence from the launch escape tower) excite vibration of increasing intensity until a maximum is reached at approximately the time of maximum aerodynamic pressure (MAX Q).
4. SPS engine operation provides the only significant source of C/M vibration during space flight maneuvers. This vibration, transferred mechanically throughout the S/C structure, can generally be expected to decrease with increasing distance from the engine. Since the RCS engines possess a very low thrust capacity, their operation will only produce modest and localized vibration (mostly due to jet impingement).

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Figure 4-27. S/C Relative Vibration Intensity Time History

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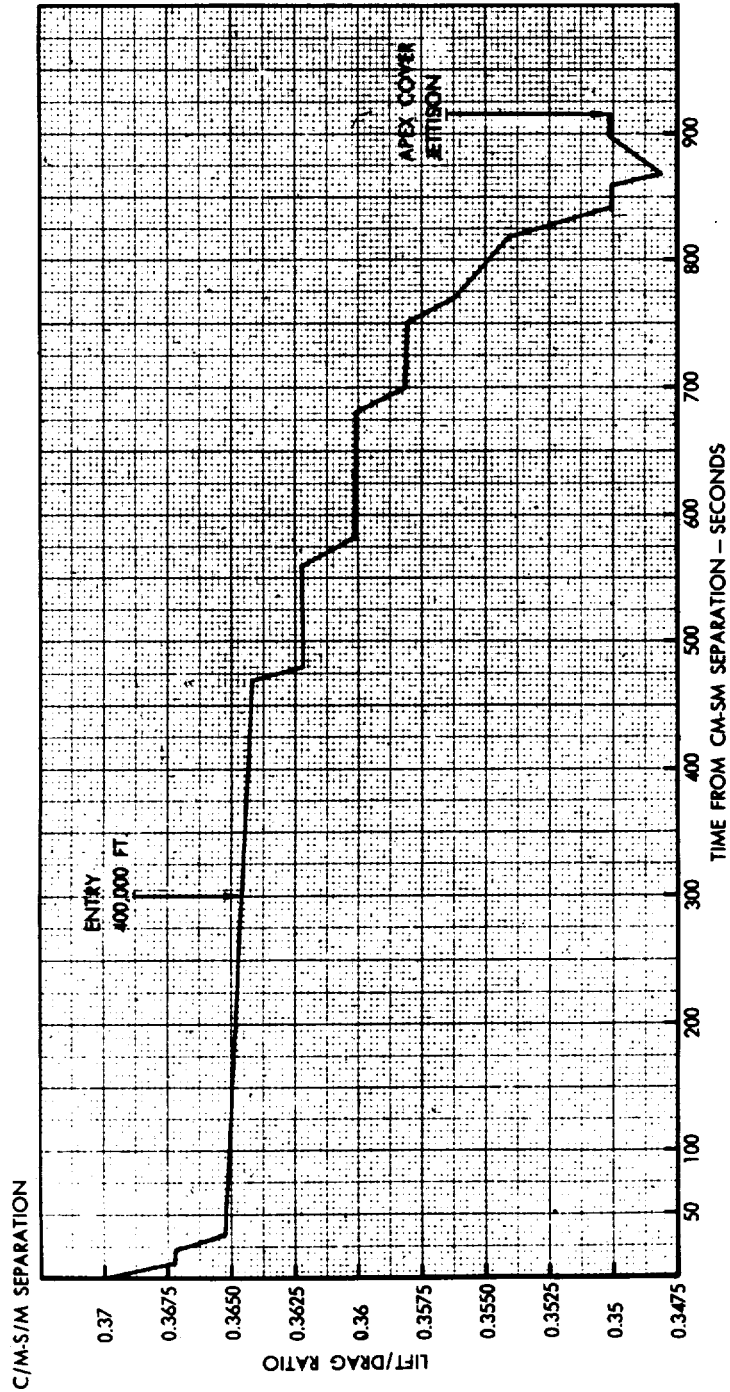
Figure 4-28. Altimeter Error and C/M Base Pressure Effects

S/C OPERATIONAL CONSTRAINTS AND LIMITATIONS



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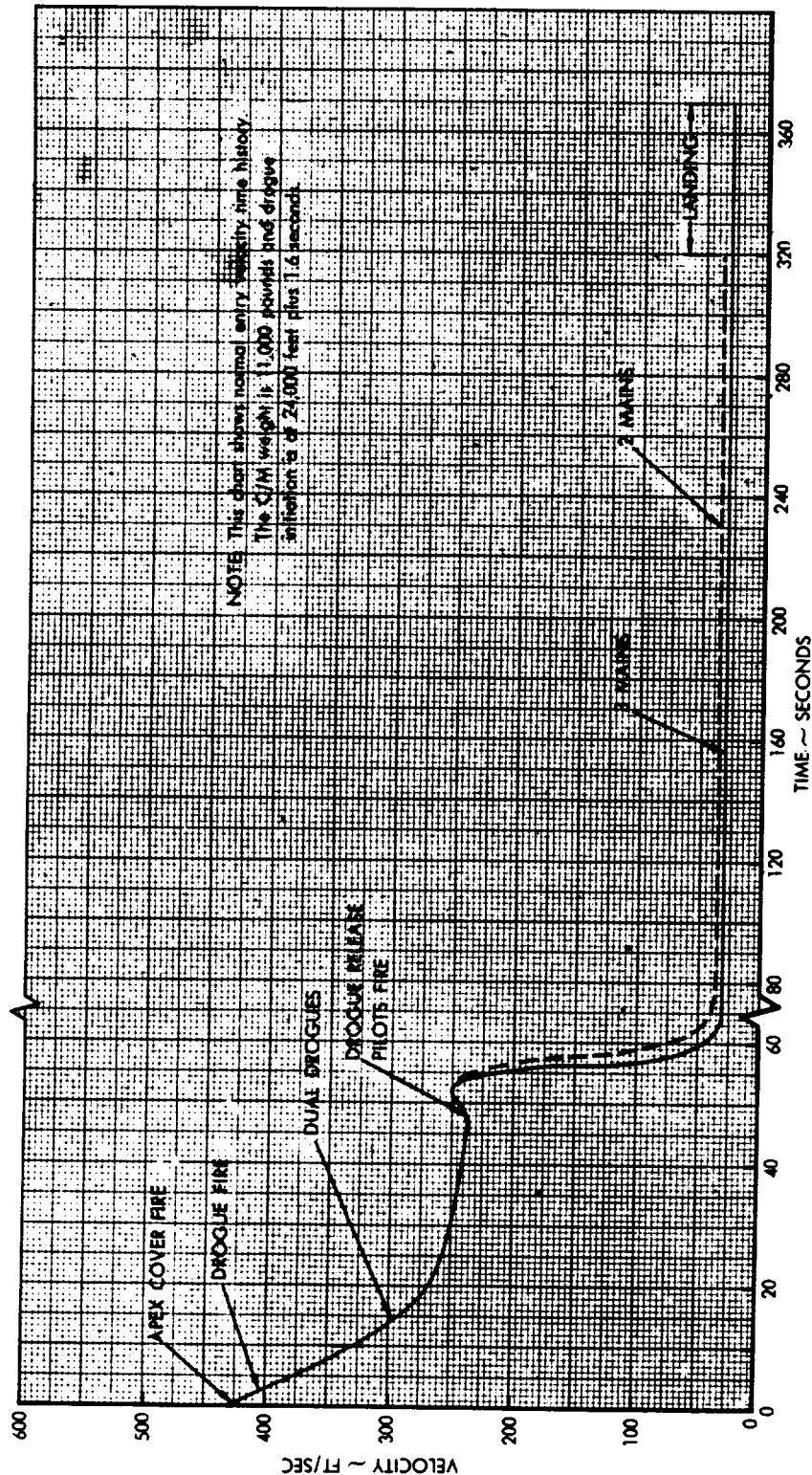


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Figure 4-29. C/M Entry - Lift/Drag Profile

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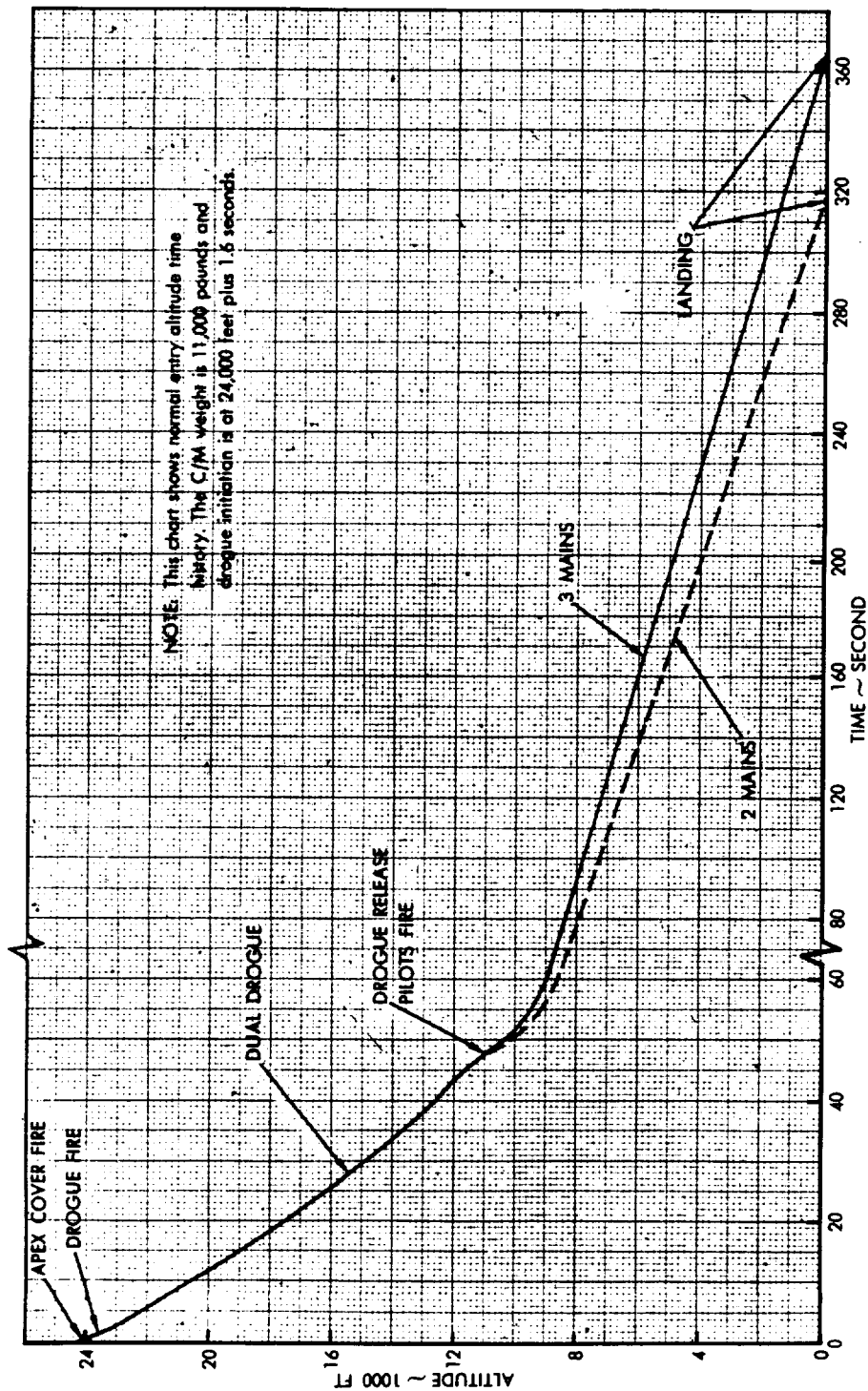


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Figure 4-30. Normal Entry - Velocity Time History

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PERFORMANCE



SM-2A-979A

Figure 4-31. Normal Entry - Altitude Time History



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SECTION 5

EXPERIMENTS AND SCIENTIFIC EQUIPMENT DATA

INTRODUCTION

This section presents the objectives of mission 204A experiments and contains a description of associated equipment, stowage areas (figure 5-1), crew participation requirements for data collection, and related scientific equipment data. The in-flight tests are categorized as medical (M-), scientific (S-), and technical (T-) experiments as follows:

- In-Flight Exerciser (M-3A) (M003)
- In-Flight Phonocardiogram (M-4A) (M004)
- Bone Demineralization (M-6A) (M006)
- Human Otolith Function (Vestibular Effects)(M-9A) (M009)
- Cytogenetic Blood Studies (M-11) (M011)
- Cardiovascular Reflex Conditioning (M-48) (M048)
- Synoptic Terrain Photography (S-5A) (S005)
- Synoptic Weather Photography (S-6A) (S006)
- In-Flight Nephelometer (T-3) (T003).

**NOTE** The Planning and Management Office of the EPO (Experiments Program Office) is the coordinating facility for all of the experiments described in this section.

The experiments stowage areas location will be found in figure 5-1.

5.1 SCIENTIFIC EQUIPMENT.

5.1.1 MEDICAL DATA ACQUISITION SYSTEM (MDAS).

The medical data acquisition system, located in compartment C (figure 5-2), weighs 15.2 pounds and consists of a seven-channel tape recorder, associated signal conditioners, junction box, time code generator, and a front panel with switches and outlets for power and signal cables. This GFE unit uses 28-volt d-c power from compartment A to acquire and permanently record on magnetic tape all required medical (operational and experimental) data. The operational data required consists of electrocardiograph and impedance pneumograph outputs, while the experimental data consists only of phonocardiograph outputs. These medical parameters are routed from sensors and signal conditioners (attached to a crewman) through the PGA or CWG adapter cable, cobra cable, T-adapter, and octopus cable to specified channels in the MDAS. Although 100 watts of electrical power is provided for the MDAS from compartment A via the octopus cable, only about 19 watts are needed to operate the integral tape

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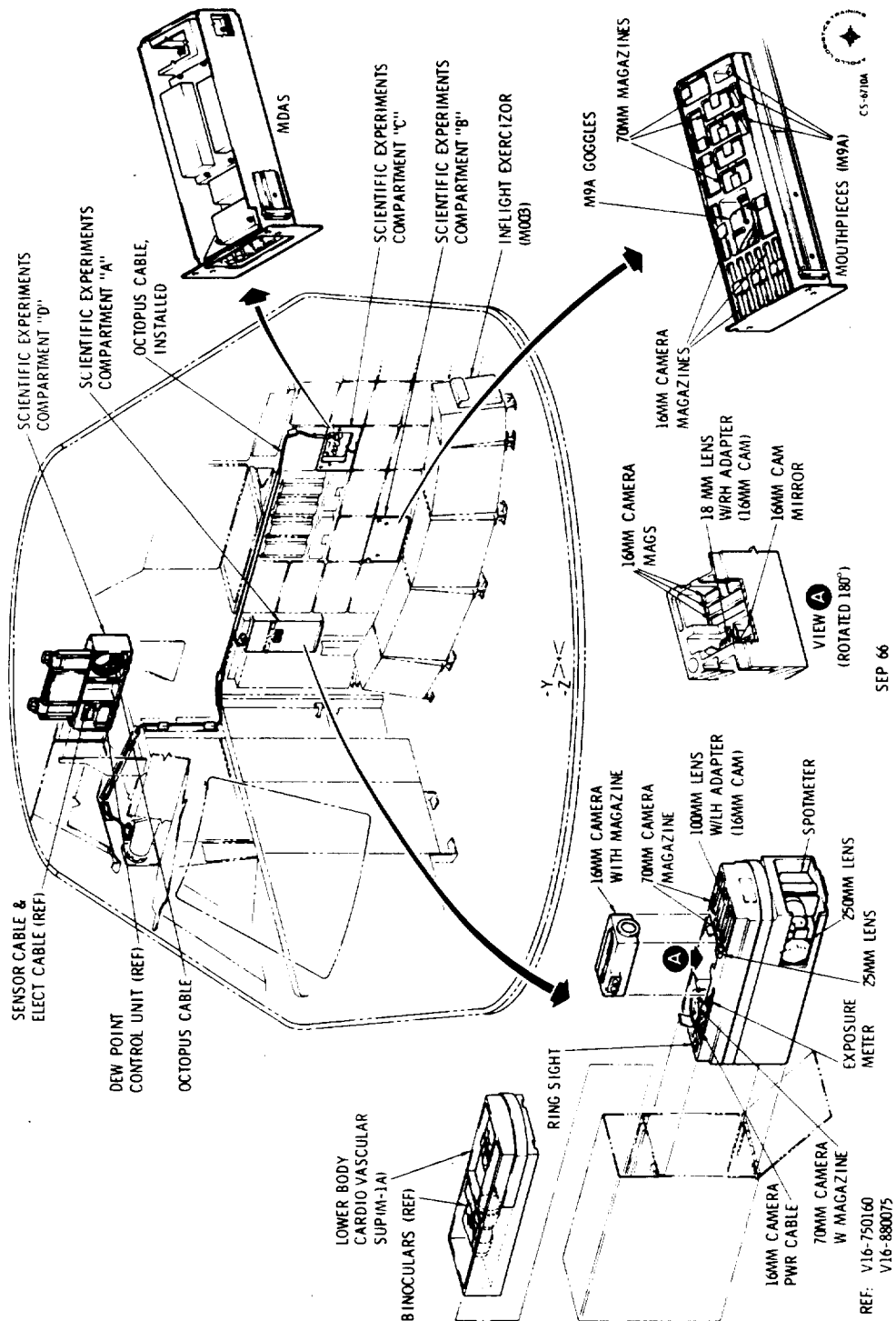


Figure 5-1. S/C 012 Mission Experiments Location, LEB (Sheet 1 of 2)

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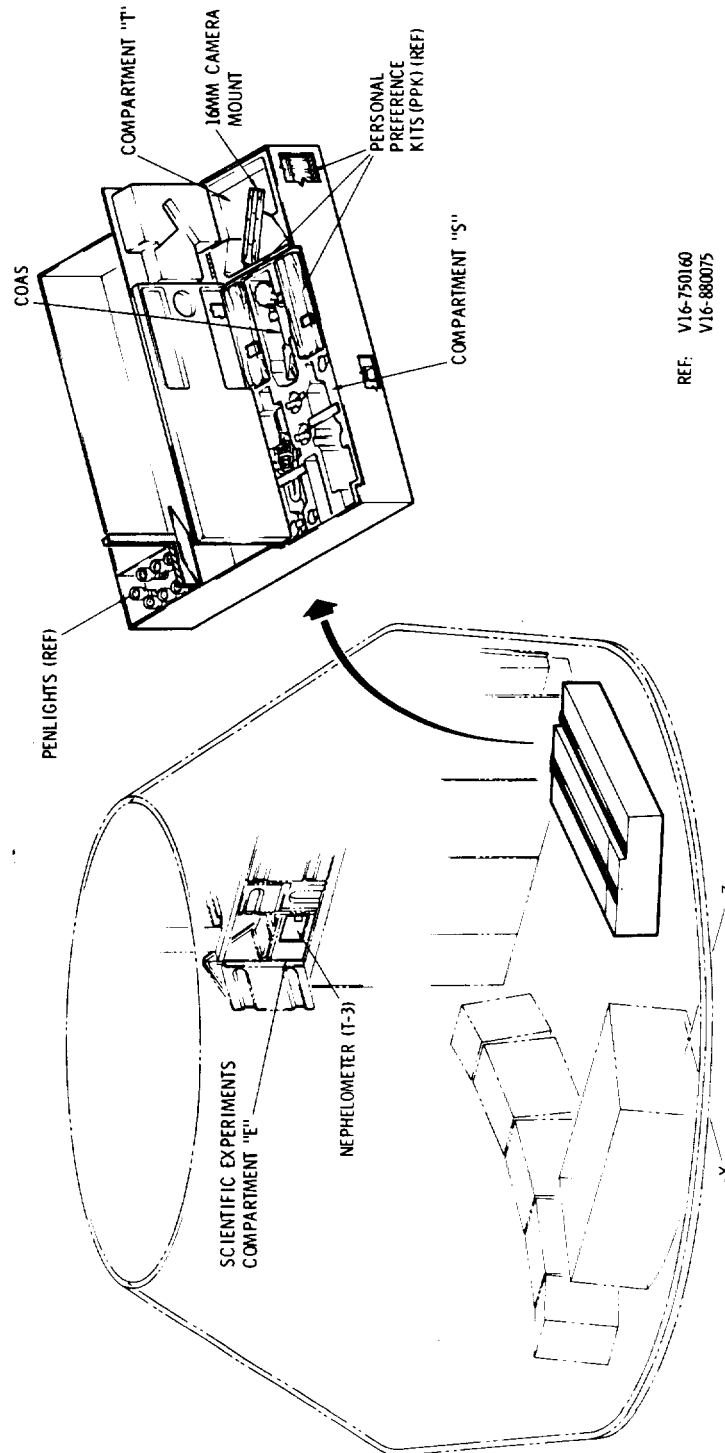


Figure 5-1. S/C 012 Mission Experiments Location, LEB (Sheet 2 of 2)

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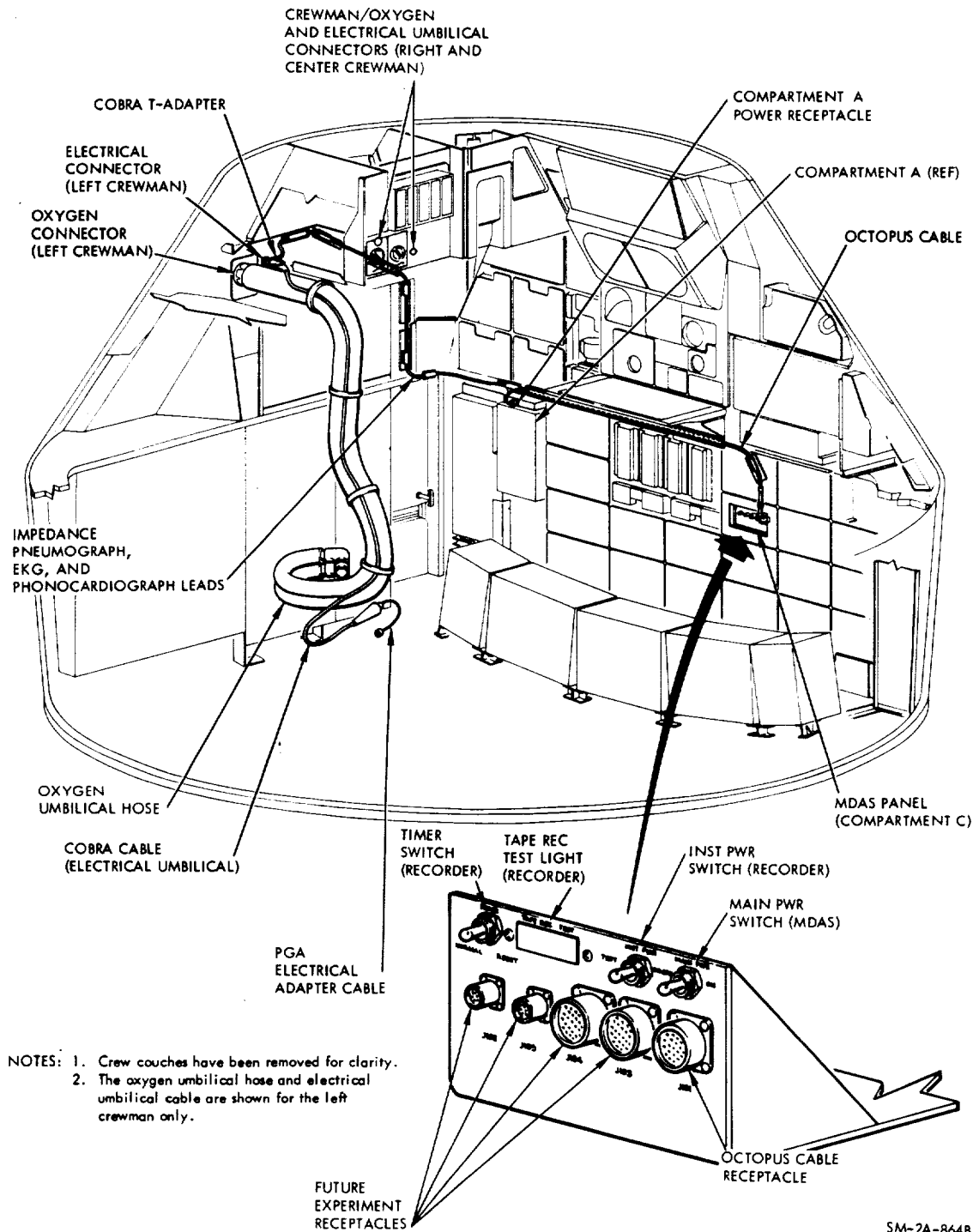


Figure 5-2. Experiments Tape Recorder and Electrical Connectors

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recorder. However, electrical outlets on the MDAS front panel are provided for additional or future experiments (via electrical cabling connected directly to the equipment and the MDAS). The MDAS front panel also contains a MAIN PWR switch for controlling power to the unit and unit outlets, an INSTR PWR switch for controlling power to the tape recorder and the recorder test light, and a TIMER switch for correlating mission elapsed time on the tape recorder.

All three crewmembers have the capability of being recorded for their physiological data when electrically connected to the tape recorder. However, only one crewman at a time will have his outputs recorded during flight. (See figure 5-3.) Total recording time for the tape recorder is 100 hours maximum with 880 feet of usable tape. There are seven channels available for collecting data (including the optional channel for recording code signals).

The MDAS tape recorder is removed from the spacecraft immediately after flight, placed in a GFE metal container for protection against strong magnetic fields, and transported to the NASA-MSC (where the magnetic tape is removed from the recorder).

5.1.2 ELECTRICAL CABLES AND ADAPTERS.

5.1.2.1 Octopus Cable.

The octopus cable (figure 5-2) plugs into the MDAS tape recorder, is protected from electrical arcing by an on-off power switch on the recorder panel, and contains signal and power lines for the following:

- Provides for 28-volt d-c (100 watts) power from compartment A to the MDAS in compartment C
- Provides for biomedical signals from a crewman (attired in the PGA or CWG) to the tape recorder. These signals consist of EKG, phonocardiograph, and impedance pneumograph outputs. This cable weighs 1.5 pounds and is stowed in compartment D of the LHFEB during launch and entry. The cable remains connected to the MDAS and a crewman's T-adapter during orbital flight.

5.1.2.2 Cobra Cable T-Adapter.

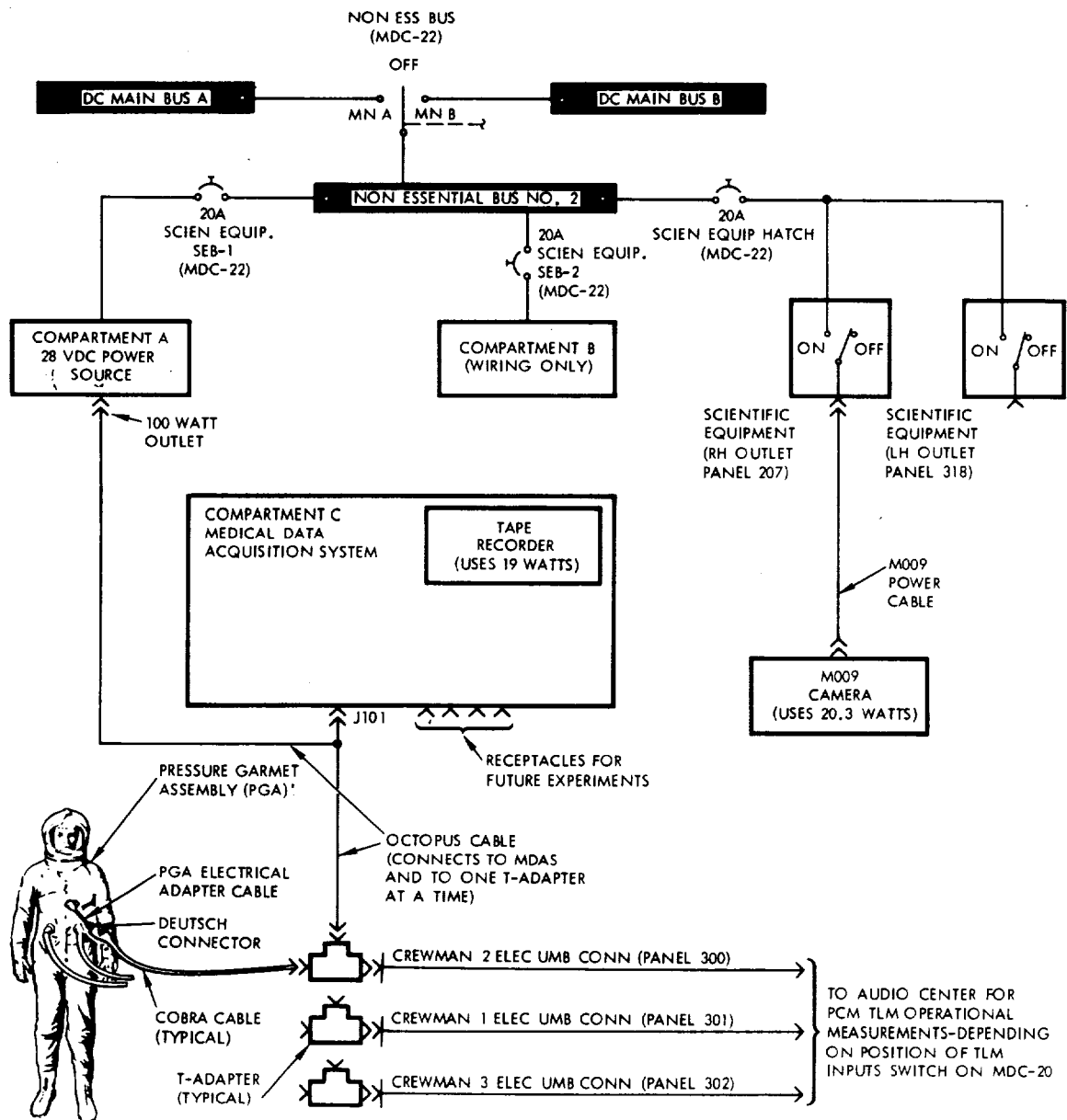
The T-adapter (figure 5-2), provided for each crewmember, weighs 1/2 pound and remains attached to the cobra cable at all times. This three-way electrical connector mates the cobra cable to the appropriate crewman electrical umbilical connector (panels 300, 301, or 302) and the octopus cable. A relay incorporated in the T-adapter is controlled by the TLM INPUTS-BIOMED (MDC-20) or the MDAS MAIN PWR switch in compartment C (providing the octopus cable lead is connected to the T-adapter). This relay permits electrical signals, from a crewman's torso, to be transmitted as operational data and recorded in-flight as experimental data.

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NOTES:

1. Signal conditioners, sensors, and associated wiring on a crewman's torso (attached to the Microdot connector inside the PGA or on the CWG) provide for PCM TLM operational measurements and scientific experiments data.
2. A T-adapter permits simultaneous transmission of operational measurements (selected for one crewman at a time) and the recording of in-flight experiments data. However, operational measurements can be transmitted from one crewman while another crewman is recording experiments data.

SM-2A-902C

Figure 5-3. Scientific Equipment Power Distribution

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Operational data from one crewman may also be transmitted while experimental data from another crewman is being taped on the MDAS. However, only one operational transmission and one experimental recording can be taken at the same time.

5. 1. 2. 3     PGA and CWG Electrical Adapter Cables.

The PGA and CWG electrical adapter cables (crew personal equipment) are provided to connect the cobra cable to signal conditioners and communication equipment attached to a crewman's body. (See figure 5-3 and refer to section 6.)

5. 1. 2. 4     Hardware Power and Signal Cables.

Hardware power and signal cables are used for connecting equipment electrically to various outlets in the crew compartment. (See figure 5-3.) Protection from electrical arcing is provided by switches on the equipment or on the outlet panels in the crew cabin. The M-9A camera power cable (figure 5-3) connects to the RH SCIENTIFIC EQUIPMENT outlet on panel 207. A SCIENTIFIC EQUIPMENT outlet on panel 318 (near the LH side window) is reserved for a future experiment but can also be used as a backup outlet for the camera cable. Outlets marked J102 through J105 on the MDAS are reserved for future experiments. (See figure 5-2.)

5. 2     MEDICAL EXPERIMENTS.

5. 2. 1     IN-FLIGHT EXERCISER (M-3A) (M003).

The purpose of experiment M-3A is to collect crew data for determining benefits of exercise during space flight. Recumbency (bed rest) studies have shown that exercise work tolerance for an individual is greatly reduced after being relatively immobile and in a horizontal position for a few days. Zero gravity during space flight may further increase the length of a crewman's reconditioning period.

5. 2. 1. 1     Equipment Description.

The exerciser for experiment M-3A (figure 5-4) weighs about 1-1/2 pounds and consists of two rubber elastic (bungee) cords with a retaining cable. A nylon elastic sleeve covers the bungee cords and retaining cable. One end of the exerciser contains a looped strap made of webbing cloth that can be secured around a crewman's feet. The other end of the exerciser has a spherical plastic handle grooved to fit both hands of a crewman. The retaining or safety cable within the elastic sleeve permits the exerciser to be stretched from 9-1/2 to 21-1/2 inches.

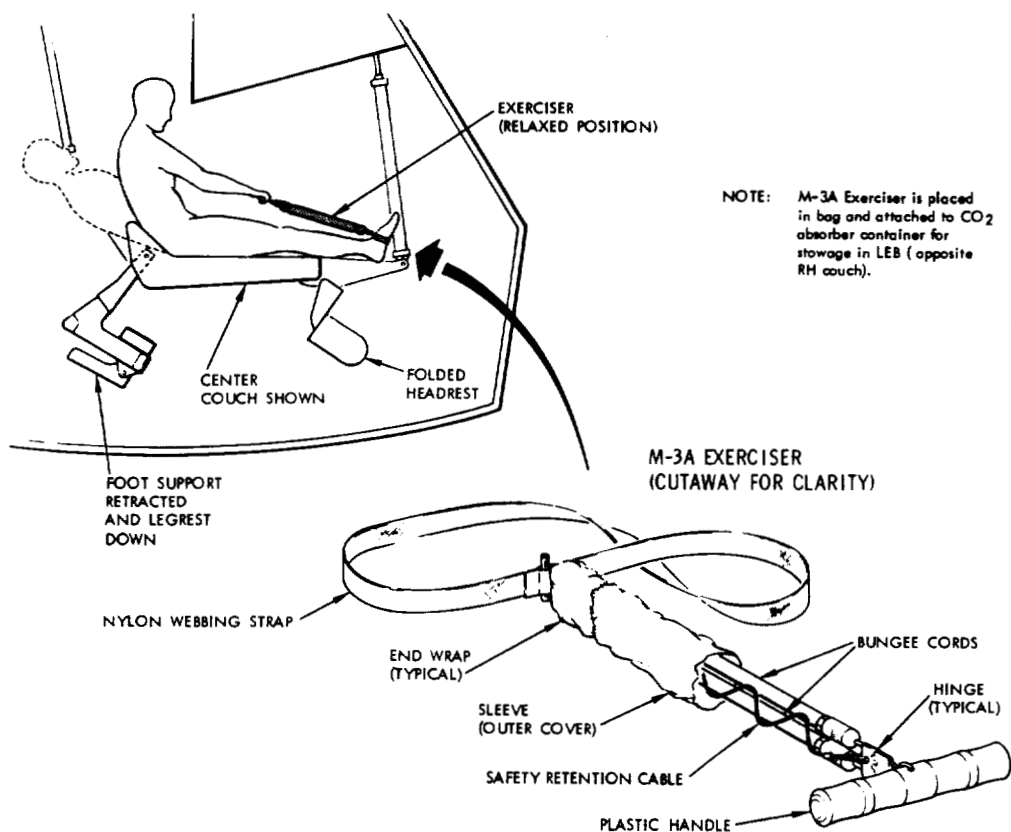
A mechanical interface between the equipment and the S/C exists where the exerciser container is attached to the CO<sub>2</sub> absorber container in the LEB (opposite the RH couch). Although all three couches can be used

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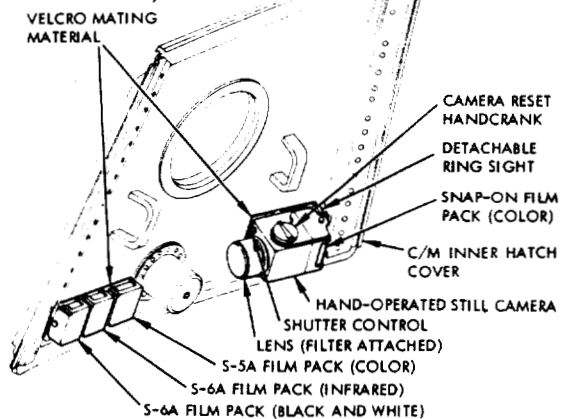
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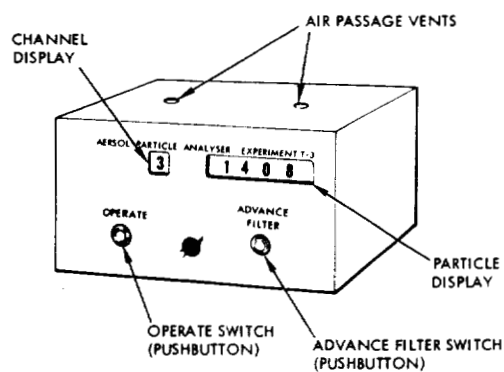


EXPERIMENTS S-5A AND S-6A

NOTE: All S-5A and S-6A experiment equipment is stowed in Compartments A and B during launch and entry.



EXPERIMENT T-3



NOTE: The nephelometer must be returned to compartment E for storage after each test analysis, if it is not provided with tie-downs or Velcro.

SM-2A-866A

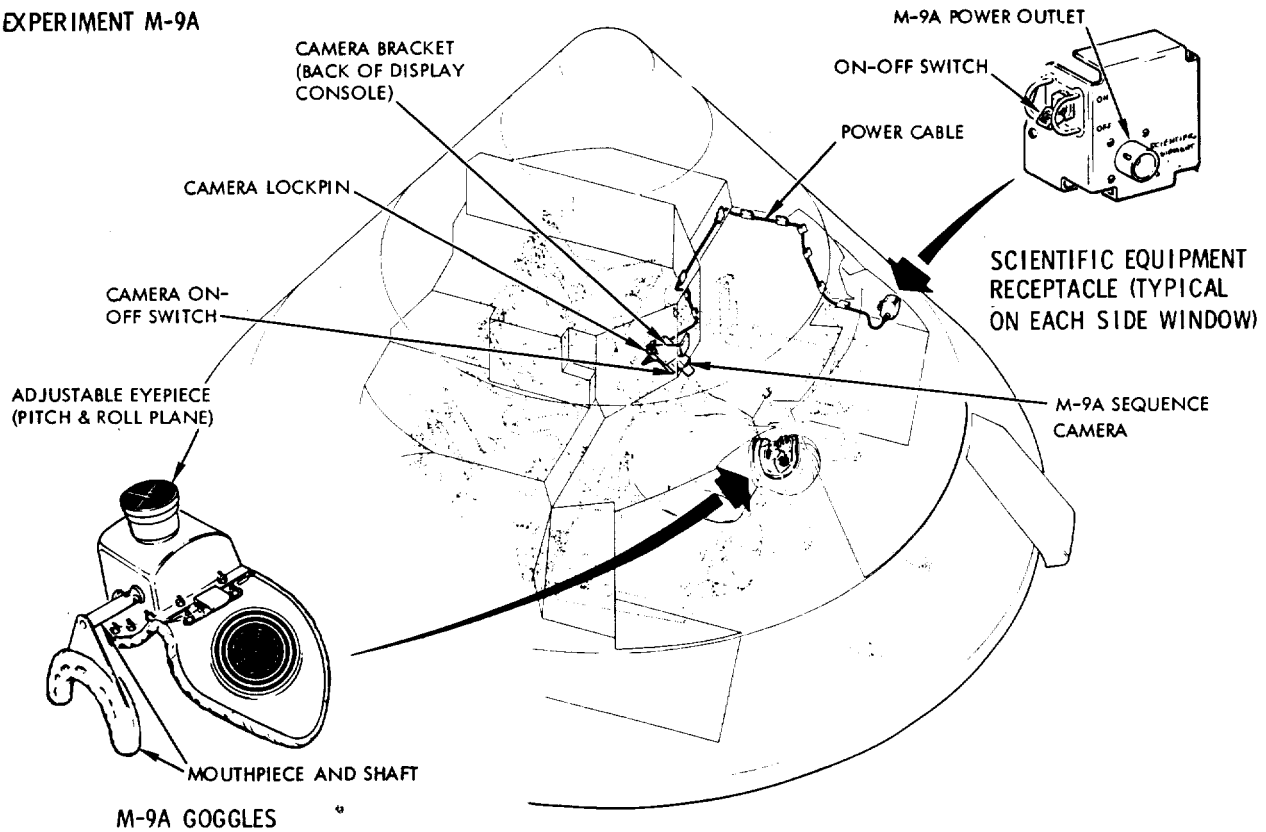
Figure 5-4. Experiments Operational Arrangement (Sheet 1 of 2)

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EXPERIMENT M-9A



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Figure 5-4. Experiments Operational Arrangement (Sheet 2 of 2)

during the M-3A isotonic and isometric exercises, only the center couch provides adequate head room to comfortably perform isotonic exercises when data recording periods are conducted. (Data includes EKG, impedance pneumograph, and phonocardiograph recordings taped on the MDAS recorder.)

5.2.1.2 Experiment Procedures.

All crewmen will exercise in-flight for 10 minutes three times every 24 hours. The base line preflight data will serve as a control for the study. A recording session is required once per day on one crewman before, during, and after an exercise period. Crewmembers will alternate each day for data recordings. (Detailed procedures are provided in section 11.)

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5.2.1.3 Crewman Participation.

Requirements for crewman participation in the exercise experiment are as follows:

- a. Preflight - Each crewman will be tested for exercise tolerance (physical fitness level) on three separate occasions 8 to 4 weeks prior to flight.
- b. In-flight - Each crewman will be required to exercise 3 times daily for 10 minutes each exercise period. Medical data from one crewman will be recorded during one exercise period each day. (It will take 3 days to obtain medical data from all three crewmen.)
- c. Postflight - Each crewman will undergo re-evaluation exercises on three separate occasions (12 to 24 hours, 1 week, and 2 weeks after touchdown).

5.2.1.4 Recovery Requirements.

There are no special recovery requirements for experiment equipment because the in-flight exerciser will remain stowed in the S/C during recovery. An exerciser of equivalent design will be available at the site where postflight evaluations are performed and the experiment is completed. The on-site coordinators will be responsible for removal of the magnetic recording tape from the MDAS and delivery of all data to the NASA-MSD.

5.2.2 IN-FLIGHT PHONOCARDIOGRAM (M-4A) (M004).

The purpose of experiment M-4A is to obtain information on the functional cardiac status of two crewman during prolonged space flight. An in-flight recording of the phonocardiographic heart sounds, compared with the highest EKG signal, will be made to determine the delta time interval between electrical activation of the heart muscle (myocardium) and the onset of ventricular systole (heart contraction).

5.2.2.1 Equipment Description.

The equipment worn by the crew commander and navigator in experiment M-4A consists of two phonocardiogram transducers (microphone biosensors), a phonocardiograph signal conditioner package (amplifier) with variable gain, and associated electrical wiring. The biosensors are attached to the crewman's torso (skin) and connected by electrical leads to the signal conditioner (fastened on the CWG) and the Microdot connector on the PGA or CWG. Signal outputs from the crewman's body to the biomedical tape recorder (compartment C) are routed via the PGA or CWG adapter cable, the cobra cable, T-adapter, and the GFE octopus cable. (See figure 5-3 for tape recorder and electrical connectors, and refer to paragraph 5-1 for data on scientific equipment.)

The total S/C electrical power for recording the experiment is approximately 1.4 watts. The octopus cable, for connecting the tape recorder to the PGA, is stowed in compartment D of the LHFEB. (See figure 5-1.)

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5. 2. 2. 2     Experiment Procedures.

Installation of phonocardiogram transducers on the chest of the two crewmen and the positioning and hookup of electrical leads, worn outside the CWG, are performed during the preflight suiting procedure. After hookup during flight, recordings are taken on the medical data acquisition system (MDAS). Supporting data such as EKG and impedance pneumograph signals are also recorded during the experiment. (Detailed in-flight procedures are provided in section 11.)

5. 2. 2. 3     Crewman Participation.

Requirements for crewman participation in the phonocardiogram experiment are as follows:

- a. Preflight - Sensor application should not exceed one hour. Approximately 5 minutes of recording will be required for collecting baseline data from each crewman.
- b. In-flight - No effort will be required by the crewman other than hookup to the MDAS. The one special exception could be time spent in determining optimum placement or repositioning of a microphone biosensor.
- c. Postflight - Approximately 5 minutes will be required for post-recovery recording for data comparison.

5. 2. 2. 4     Recovery Requirements.

There are no special recovery requirements for the experiment other than removal of the magnetic recording tape from the MDAS. The recorded data will be processed by conventional methods.

5. 2. 3     BONE DEMINERALIZATION (M-6A) (M006).

The purpose of experiment M-6A is to determine the effect of weightlessness and immobilization during space flight on the demineralization of certain bones within the body of each astronaut.

5. 2. 3. 1     Equipment Description.

This experiment does not require any in-flight equipment, S/C power or fuel, or recording equipment. (There are no interface problems between experiment M-6A and the S/C.)

5. 2. 3. 2     Experiment Procedures.

In-flight procedures are not required for this experiment. Prior to flight, crewmen will have X-rays taken of their heel bones and the last joint of the little finger on the right hand. These exposures will be taken before and after flight at Kennedy Space Center X-ray facilities. The hematopoietic (i. e., blood forming marrow) areas will not be exposed to the radiation source since the exposure field will be carefully limited.

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5.2.3.3     Crewman Participation.

Requirements for crewman participation in the bone demineralization experiment are as follows:

- a. Preflight - Approximately 45 minutes total time is required per crewman for obtaining X-ray films (three 15-minute sessions at T minus 10 days, T minus 2 days, and T minus 220 minutes).
- b. In-flight - None
- c. Postflight - Approximately 15 minutes per astronaut are required for obtaining X-ray films after spacecraft recovery. (A follow-on checkup may be required, depending on bone demineralization.)

5.2.3.4     Recovery Requirements.

On-site investigators will develop X-ray films, make bone densitometry measurements, and be responsible for delivery of all data to the NASA-MSC.

5.2.4     HUMAN OTOLITH FUNCTION (VESTIBULAR EFFECTS) (M-9A) (M009).

The purpose of experiment M-9A is to determine the effect of prolonged weightlessness on a crewman's orientation sensation, particularly to the otolith organ (inner ear). All data collected will be used to predict the ability of space crews to orient themselves in a weightless environment, especially when subjected to darkness (eyes covered).

5.2.4.1     Equipment Description.

The equipment used for the experiment consists of the otolith test goggles (a mask with a single eyepiece or monocular scope), a mouthpiece for each crewman to align the goggles with his head, a 16 mm sequence camera (part of the operational equipment), film packs for recording the actual orientation of the subject's head relative to the S/C, and an electrical cable for providing 28-volt d-c power to the camera. (See figures 5-1 and 5-4.)

A bracket, stowed in compartment T on the aft bulkhead, is mounted behind the main display panel in the egress tunnel to secure the camera during the experiment. The experiment goggles and mouthpieces weigh about 5 pounds and are stowed with most of the film packs in compartment B of the LEB. Additional film packs and the power cable are kept in compartment A with the operational camera and lens. The 28-volt d-c power source for the camera is provided by an outlet near the crew cabin RH side window. (See figure 5-4.)

5.2.4.2     Experiment Procedures.

In preparation for the experiment, shades are installed over the windows and all cabin lights are turned on to maximum intensity. The test

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subject (in the center couch) operates the camera, covers his eyes with the otolith test goggles, and manually adjusts a self-luminous target line in the monocular scope to what he thinks is straight ahead and parallel to the S/C Y-Y axes. A series of adjustments will be recorded by the camera (for each crewman) during flight and compared to test results obtained during preflight and postflight tests. (Detailed in-flight procedures are provided in section 11.)

5.2.4.3 Crewman Participation.

Requirements for crewman participation during the experiment are as follows:

a. Preflight - A total time of about 3 hours is required for familiarization and training, including collection of base line data (for all three crewmen).

b. In-flight - One test period of 15 minutes per day per crewman is required.

c. Postflight - Each crewman will be subjected to a 5-minute test period as soon as possible after S/C recovery (for a total time of about 15 minutes) to complete the experiment data.

5.2.4.4 Recovery Requirements.

Facilities in the primary recovery area will be used to complete the postflight examination and medical debriefing. The raw data consisting of film is recovered from the S/C along with the goggles and mouthpiece for delivery to the on-site coordinators.

5.2.5 CYTOGENETIC BLOOD STUDIES (M-11) (M011).

The purpose of experiment M-11 is to conduct preflight and postflight analyses to determine if space environment produces cellular changes in the blood of crewmen. These changes, which are important to the medical and scientific point of view, may not be apparent from routine monitoring procedures.

5.2.5.1 Equipment Description.

This experiment does not require any in-flight equipment, S/C power or fuel, or S/C recording equipment. (There is no interface between experiment M-11 and the S/C.)

5.2.5.2 Equipment Procedures.

On two occasions (preflight), approximately one month apart, blood specimens will be obtained from the crewmen for the experiment. The second occasion for drawing blood samples will be scheduled as close to lift-off time as conveniently possible. Blood samples for part A of the experiment (cytogenic studies of human hemic cells) and part B of the

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experiment (immunological system) will be drawn at a predetermined hospital site for analyses. Postflight requirements will be essentially the same, except that three such samples will be required over a period of one year. The first postflight blood sample will be drawn shortly after the termination of flight. (In-flight procedures are not required for this experiment.)

5.2.5.3 Crewman Participation.

Requirements for crewman participation in the M-11 experiment are as follows:

- a. Preflight - On two occasions prior to flight (T minus 30 days and T minus one day), blood samples (10 cc for part A and 15 to 20 cc for part B of the experiment) will be drawn from each crewman.
- b. In-flight - None
- c. Postflight - On three occasions after S/C recovery, blood samples (10 cc for part A and 15 to 20 cc for part B of the experiment) will be drawn from the crewmen. It is not essential that blood samples for parts A and B are drawn at the same time.

5.2.5.4 Recovery Requirements.

After mission completion, blood samples must be drawn from the crewmen at a conveniently located, but predetermined, hospital for analyses. Blood determinations made should include immunoelectrophoresis, electrophoresis, electrophoresis on starch gel, measurement of gamma<sub>2</sub>, gamma<sub>1</sub>, and gamma M globulin levels, measurement of whole hemolytic complement, titration of blood group antibodies, and measurement of pre-existent, antibacterial antibodies.

5.2.6 CARDIOVASCULAR REFLEX CONDITIONING (M-48) (M048).

The purpose of experiment M-48 is to determine the effectiveness of a lower body vascular support garment for preventing physical fatigue, insufficient circulating blood volume to maintain adequate venous return (blood-pooling), and a loss of venomotor reflexes in the legs of a crewman during entry and recovery (when exposed to earth 1-g gravity force).

5.2.6.1 Equipment Description.

The equipment used in experiment M-48 consists of an 8-ounce pair of waist-length tights for supporting veins in the lower portion of a crewman's body. These tights are composed of rubber strands wrapped with cotton and woven into a garment with dacron. When worn, the tights will extend from the crewman's waist to his heel and supply a decreasing pressure from the waist down. The M-48 equipment does not require any S/C electrical power, fuel for attitude maneuvers, or recording equipment. When not in use, the experiment tights are stowed in compartment A of the LEB.

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5.2.6.2     Experiment Procedures.

The M-48 vascular support tights are donned by a crewman prior to entry and just before getting into the pressure garment assembly (PGA). This crewmember also wears a two-piece constant wear garment (CWG) to facilitate getting into the tights and replacing the CWG. (Detailed in-flight procedures are provided in section 11.)

5.2.6.3     Crewman Participation.

Requirements for crewman participation in the conditioning experiment are as follows:

a. Preflight - Each crewmember will be given a minimum of three tilt-table checkouts for control data (requiring about 90 minutes per crewman). These checkouts, performed by qualified flight surgeons or experiment medical team, will be conducted within 4 weeks of launch date.

b. In-flight - The in-flight portion of the experiment will consist of one crewmember donning the vascular support garment 1 to 2 hours prior to entry and wearing it until the first postflight tilt-table checkout. A total time of about 3 minutes will be required for in-flight experiment preparations.

c. Postflight - After recovery, a series of tilt-table tests will be given to both the control subjects and the experiment subject. The control subjects will be tested 2 to 4, 8 to 12, 24, and 48 hours after recovery. The experiment subject, wearing the vascular support garment, will be initially tested 2 to 4 hours after recovery. Twenty minutes after his first tilt-table test, the experiment subject will be given a second test without the support garment. The remaining tests will follow the same sequence as described for the control subjects.

**NOTE** Tilt-table checkouts for the experiment consist of a 5-minute supine tilt, a 15-minute vertical (70-degree head-up position) tilt, and a 5-minute supine recovery tilt. During each tilt phase, performed on a manual tilt table with a saddle support, the crewmember's blood pressure and heart rate will be automatically recorded each minute. Also, changes in the leg blood volume will be measured each minute during the 70-degree and supine recovery tilts.

- Additional data required to complete the experiment such as plasma volume, total blood volume, and red blood cell mass will be obtained during preflight and postflight hematology tests by the experiment medical team.

5.2.6.4     Recovery Requirements.

Tilt table, heart rate, blood pressure, and other medical support equipment for the experiment are required in the recovery area for collection of postflight data (gathered and processed by the experiment medical team).

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5.3        SCIENTIFIC EXPERIMENTS.

5.3.1     SYNOPTIC TERRAIN PHOTOGRAPH (S-5A) (S005).

The purpose of experiment S-5A is to obtain photographs of selected areas of the earth from the S/C at orbital altitude. These photographs are required for research in geology, geophysics, geographys, oceanography, and for use in planning photography from a manned orbiting laboratory.

5.3.1.1   Equipment Description

The equipment used in experiment S-5A (figure 5-4) weighs about 5 pounds and consists of a hand-operated Hasselblad 70-mm general purpose camera (single frame) with a detachable ring sight, two color-film packs (55 exposures each), and an exposure dial and spotmeter (operational equipment used with the Hasselblad camera). Except for the film packs in compartments A and B, most of the camera equipment is stowed in compartment A. (See figure 5-1.) This equipment can be retrieved and set up for photography in about 5 minutes.

No special interface problems are anticipated for this experiment. When not in use, the camera may be temporarily secured to the inner hatch cover, or anywhere within the C/M where Velcro mating material is provided.

5.3.1.2   Experiment Procedures.

This experiment will consist of photographing certain areas and features along the S/C flight path. The desired camera angle for taking pictures (with S/C window in shade) will be 90 degrees from S/C level flight over the earth. The crewman will be required to record the time of each photograph, subject, frame number, and film pack number in the experiments log book. (Detailed in-flight procedures are provided in section 11.)

5.3.1.3   Crewman Participation.

Requirements for crewman participation in experiment S-5A (time shared with experiment S-6A) are as follows:

- a. Preflight - The crewman-subjects will be provided with a briefing (1 to 3 hours) on the aims, methods, and procedures for in-flight photography of selected terrestrial areas.
- b. In-flight - About 45 minutes (total time) will be devoted to photography during 9:00 AM to 3:00 PM local time conditions.
- c. Postflight - About one hour will be required for debriefing.

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5.3.1.4      Recovery Requirements.

There are no recovery requirements other than removal of the camera and film from the S/C. Personnel performing the postflight debriefing will be responsible for delivering the exposed film to the coordinating facility for processing, analysis, and evaluation.

5.3.2      SYNOPSIS WEATHER PHOTOGRAPHY (S-6A) (S006).

The purpose of experiment S-6A is to obtain selective, high-quality photographs of cloud patterns taken from the spacecraft at orbital altitude. These photographs will be used for studies of weather system structures around the earth.

5.3.2.1      Equipment Description.

The basic equipment used in experiment S-6A (figure 5-4) is the same as that used in experiment S-5A. In addition to the 70-mm general purpose camera and ring sight, the S-6A equipment includes an ultraviolet filter, one color-film pack, and one color-shifted infrared film pack. Except for the film packs in compartments A and B, most of the camera equipment is stowed in compartment A.

No special interface problems are anticipated for this experiment. When not in use, the camera may be temporarily secured to the inner hatch cover or anywhere within the C/M where Velcro mating material is provided.

5.3.2.2      Experiment Procedures.

This experiment will consist of photographing certain weather areas and cloud formations of special interest along the S/C flight path. (Detailed in-flight procedures are provided in section 11.)

5.3.2.3      Crewman Participation.

Requirements for crewman participation (time shared with experiment S-5A) in experiment S-6A are as follows:

- a. Preflight - The crewman-subjects will be provided with a briefing (1 to 3 hours) on the aims, methods, and procedures for in-flight photographing of selected cloud formations.
- b. In-flight - As required during 9:00 AM to 3:00 PM local time conditions (about 45 minutes total time will be devoted to photography).
- c. Postflight - About one hour will be required for debriefing.

5.3.2.4      Recovery Requirements.

There are no recovery requirements other than removal of the camera and film from the S/C. Personnel performing the postflight debriefing will be responsible for delivering the exposed film to the coordinating facility for processing, analysis, and evaluation.

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5.4        TECHNICAL EXPERIMENTS.

5.4.1     IN-FLIGHT NEPHELOMETER (T-3) (T003).

The purpose of experiment T-3 (figure 5-4) is to determine and obtain a quantitative evaluation of the size, concentration, and distribution of particles present in the C/M crew compartment. In-flight measurements will be made of particles in the 0.3 to 10 micron size.

5.4.1.1   Equipment Description.

The nephelometer is a portable, self-contained instrument approximately 7.2 by 3.5 by 5.2 inches in size, weighs about 5.5 pounds, contains its own battery power supply, electronics, air pump, and presents a readout display (five channels for particle sizes in five discrete ranges). This equipment provides a collimated light beam that is focused at a point in a moving path of grossly filtered air. The cabin atmosphere, when being evaluated for aerosol particles, is drawn through the particle size detector by the air pump within the analyzer.

There are no interface problems anticipated for this experiment. When not in use, the nephelometer is stowed in compartment E of the LEB. (See figure 5-1.)

5.4.1.2   Experiment Procedures.

Experiment T-3 requires that the nephelometer be initially positioned in a preselected area within the crew compartment for evaluating particles present in the cabin atmosphere. The concentration of aerosol per unit volumes will be determined in each of five ranges (0.3 to 0.6, 0.6 to 1.2, 1.2 to 2.4, 2.4 to 4.8, and above microns). Data will be recorded after each 2-minute test run has been conducted, once every 6 hours. Several different locations may be used for taking particle measurements after the first 2 days of flight. (Detailed in-flight procedures are provided in section 11.)

**NOTE** To ensure accurate determinations, do not use analyzer if visible particles are floating in cabin; if temperature is above 90°F; or if relative humidity in cabin is over 70 percent.

5.4.1.3   Crewman Participation.

Requirements for crewman participation in experiment T-3 are as follows:

- a. Preflight - The crewman-subjects will be provided with sufficient time for equipment familiarization and training.

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b. In-flight - Experiment measurements will be conducted once every 6 hours (for a 2-minute test run) until the nephelometer integral battery power is depleted. (The total duration of the experiment is limited by a battery with a 3-hour lifetime.)

c. Postflight - About one hour will be required for debriefing.

5.4.1.4 Recovery Requirements.

The recovery requirements will consist of removing the nephelometer and recorded data from the S/C. Personnel performing the postflight debriefing will be responsible for delivering data to the coordinating facility for analysis and evaluation.

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TECHNICAL EXPERIMENTS





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SECTION 6  
CREW PERSONAL EQUIPMENT

INTRODUCTION.

This section contains a description of Contractor-furnished crew personal equipment and spacecraft interface data on NASA-furnished crew personal equipment. All major items are identified as Contractor-furnished equipment (CFE), Government-furnished equipment (GFE), or Government-furnished property (GFP).

The following is a list of equipment or subsystems for which coverage is provided.

- Crew Compartment Configuration
- Sighting Systems (GFE)
- Space Suit Assembly (GFP)
  - 1. Constant Wear Garment (GFP)
    - (a) Communication Hat (GFP)
  - 2. Pressure Garment Assembly (GFP)
- Crew Couches (CFE)
- Restraint Methods (CFE)
- In-flight Data Package (GFE)
- Crewman In-flight Tool Set and Work/Food Shelf (CFE)
- Crew Water (CFE)
- Food (GFP)
- Personal Hygiene (GFP)
- Medical Supplies and Monitoring (GFP)
- Survival Kit (GFP)
- Stowage

6.1 CREW COMPARTMENT CONFIGURATION AND CREW ENVIRONMENT.

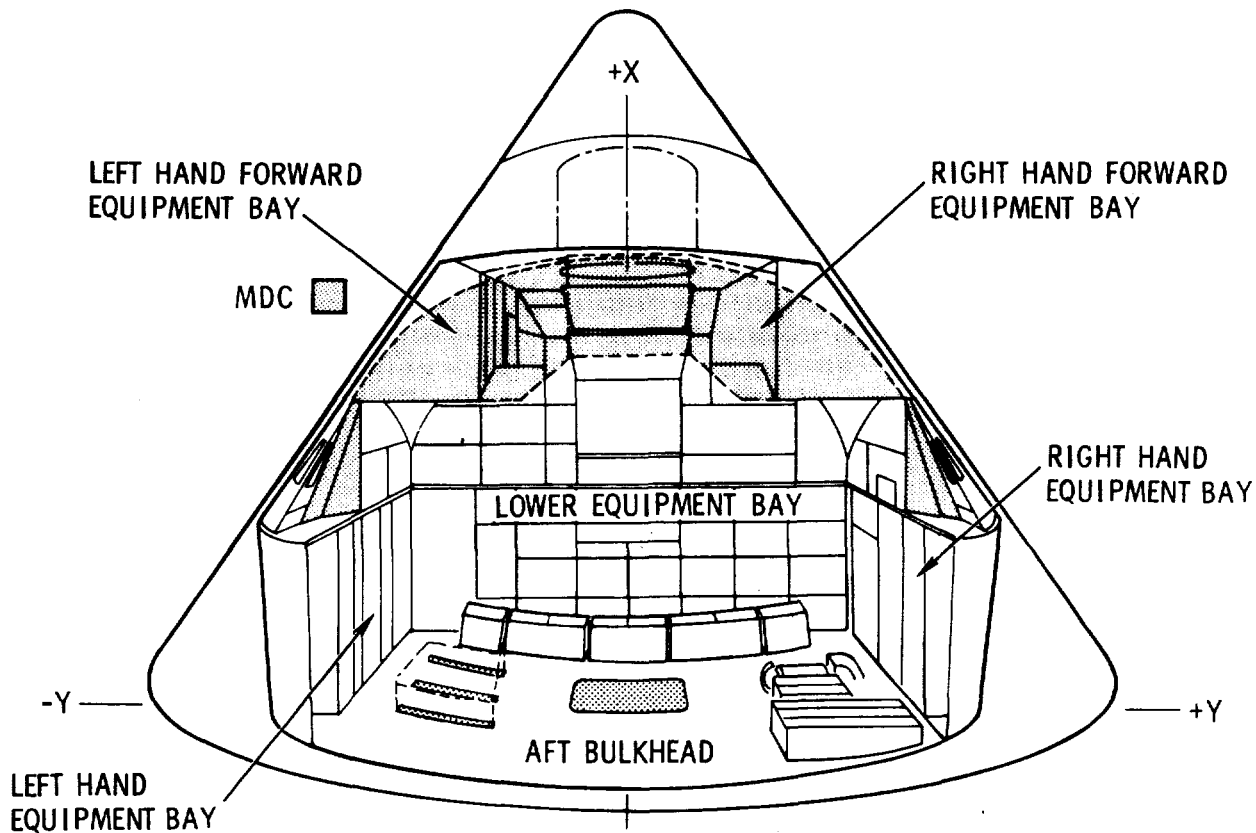
The crew compartment is the pressurized compartment within the airtight inner structure (figure 6-1). The total volume within the inner structure is 366 cubic feet. Approximately 121 cubic feet of this pressurized space is occupied by the equipment bays, and control and display consoles surrounding the crew. The couches, astronauts, aft bulkhead equipment, and miscellaneous equipment occupy another 35 cubic feet making a total of 156 cubic feet. There is approximately 210 cubic feet of usable air space. The crew compartment is pressurized to  $5 \pm 0.2$  psi, with 100 percent oxygen atmosphere and approximately 50 percent humidity.

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CREW COMPARTMENT CONFIGURATION AND CREW ENVIRONMENT

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Figure 6-1. Apollo Crew Compartment, Internal View Form -Z-Axis

6.2 MIRRORS.

6.2.1 INTERNAL VIEWING MIRRORS (CFE). (Figure 6-2)

When the astronaut is in the pressure suit, pressurized, and on the couch, his field of vision is very limited. He can see only to the lower edge of the main display console (MDC), thus blanking out his stomach area where his restraint harness buckling and adjustment takes place. The internal viewing mirrors aid the astronaut in buckling and adjustment of the restraint harness and locating couch controls.

There are three mirrors, one for each couch position. The mirrors for the left and right astronaut are mounted on the side of the lighting and audio control console above the side viewing window and fold. The center astronaut's mirror is mounted on the left X-X head attenuator strut.

CREW COMPARTMENT CONFIGURATION AND CREW ENVIRONMENT—MIRRORS

CREW PERSONAL EQUIPMENT

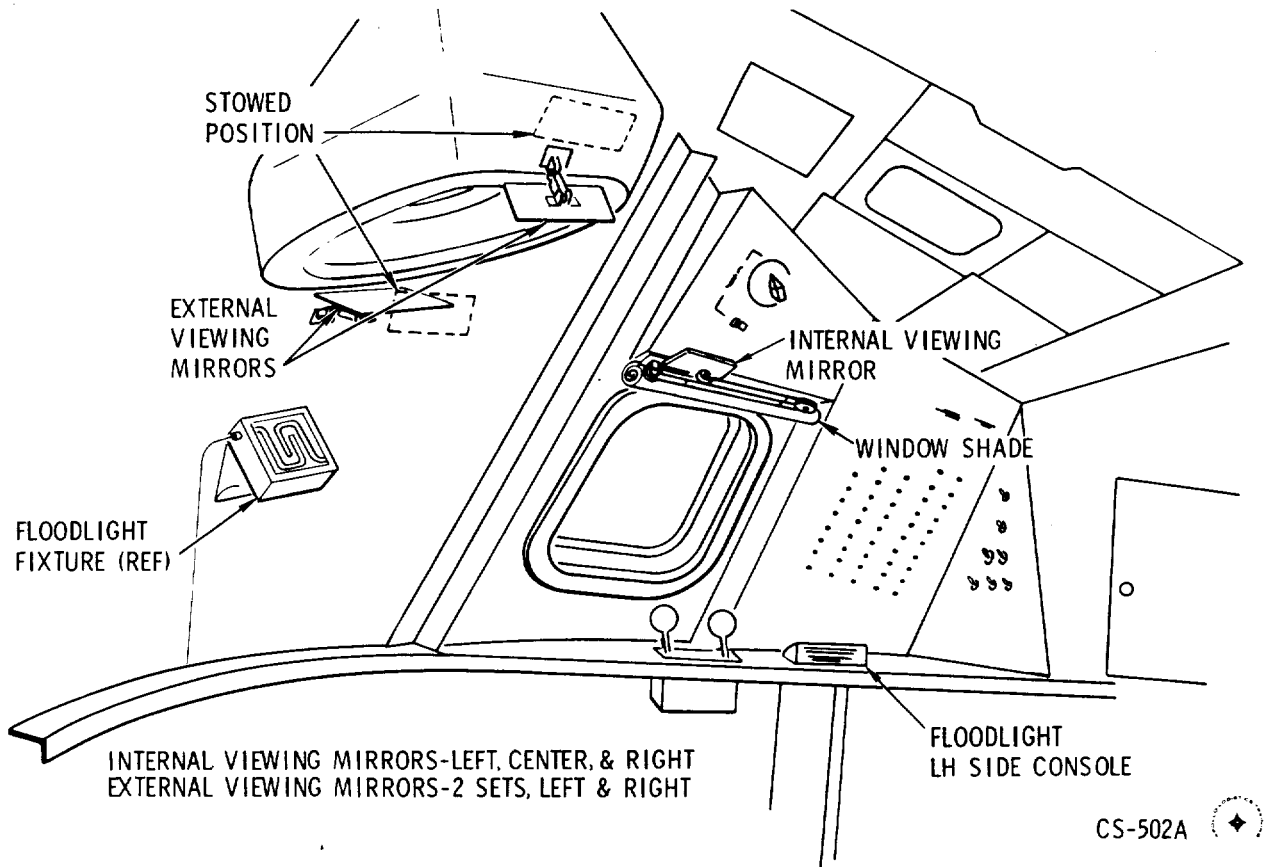


Figure 6-2. CM Mirrors, Block I and II

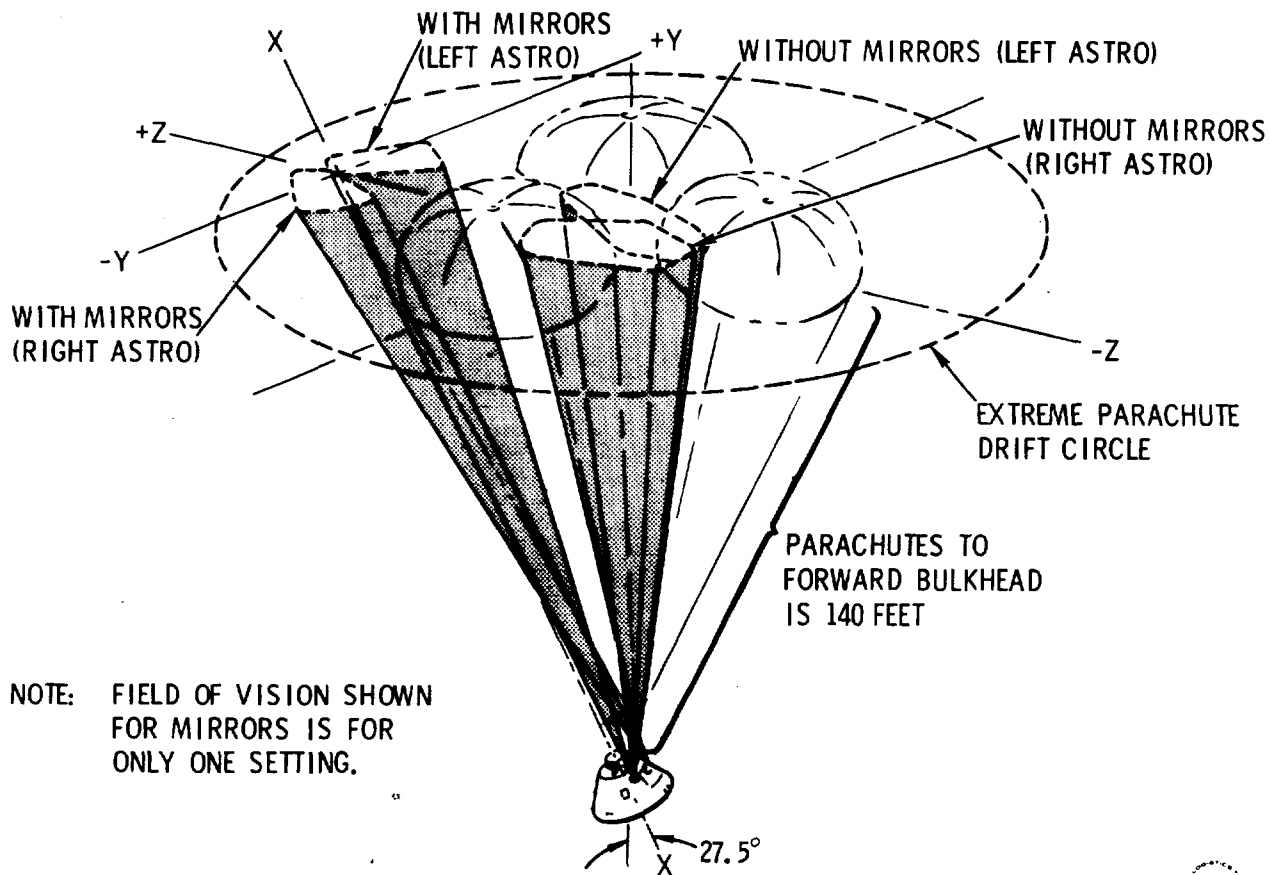
The mirror assembly consists of a mounting base, a two-segmented arm, and a mirror. The mirror is rectangular (4 by 6 inches), flat, rear surfaced, with a demagnification factor of 1:1. The two-segmented arm allows a reach of approximately 22 inches from the mount. The ends of the arm have swivel joints to position the mirrors in the desired angles. The mirrors are locked in position by a clamp during boost and entry.

6.2.2 EXTERNAL VIEWING MIRRORS (CFE). (Figure 6-2)

With the couches in the 96-degree position, the astronaut's left and right view, through the rendezvous windows, is restricted to +5 degrees to +42 degrees from the X-axis. Therefore, two sets of external viewing mirrors are installed in the CM to permit verification of parachute deployment during entry (figure 6-3). Another function is orientation of the command module in the event of an abort.

MIRRORS

CREW PERSONAL EQUIPMENT



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Figure 6-3. Parachute Field of Vision in Couch 96-Degree Position

A set of mirrors consist of an upper mirror assembly and a lower mirror assembly. The upper mirror assembly is mounted on the side wall near the upper rim on the rendezvous window frame. The lower mirror assembly is mounted on the rendezvous window housing near the lower rim of the window frame.

The mirror assembly consists of a mirror and a bracket. The bracket has a short arm with a swivel that allows positioning of the mirror. The short arm has a lock to immobilize the mirror during landing. The mirrors will have a 1:1 magnification factor and are rectangular in shape.

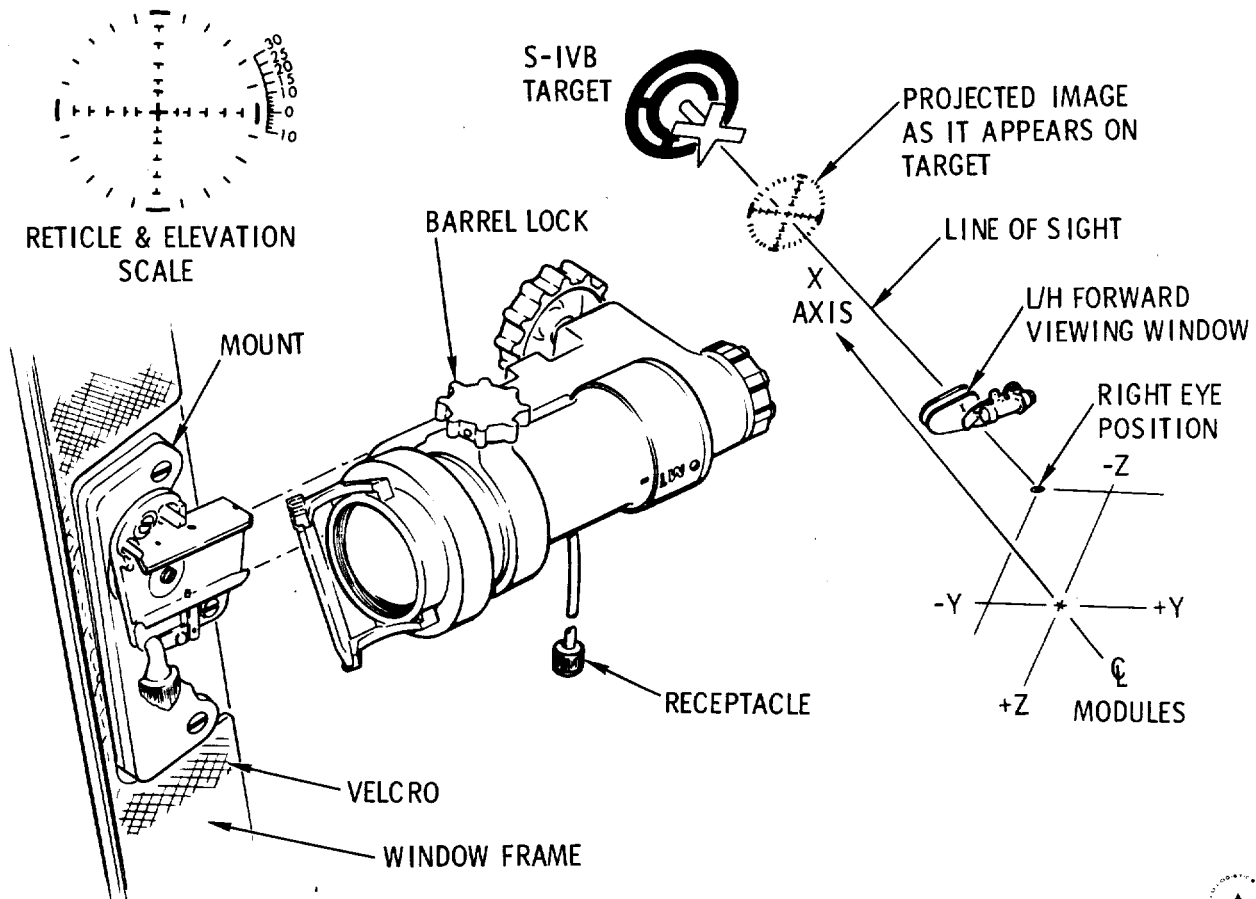
6.3

CREWMAN OPTICAL ALIGNMENT SIGHT (COAS). (Figure 6-4)

The crewman optical alignment sight provides the crewman a fixed line-of-sight attitude reference image which, when viewed through the forward window, appears to be the same distance away as the target. This image is foresighted (by means of a sight mount) parallel to the centerline (X-axis) of the CM and perpendicular to the Y-Z plane.

MIRRORS—CREWMAN OPTICAL ALIGNMENT SIGHT (COAS).

CREW PERSONAL EQUIPMENT



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Figure 6-4. Apollo Crewman Alignment Sight System Configuration

The sight is a collimator device, similar to a gunsight. It weighs approximately 1.5 pounds and is 8 inches in length. It has a cord and receptacle and requires a 28-vdc power source. The sight is stowed in compartment T during boost and entry. When operationally required, it is mounted at the left rendezvous window frame. The power receptacle is connected to the SCIENTIFIC EXPERIMENTS receptacle (on the girth shelf).

6.3.1 OPERATIONAL USE.

When photographing activities or scenes outside the spacecraft with the 16 mm sequence camera, the COAS is used to orient the spacecraft and aim the camera. The camera will be mounted on the left sidewall handhold at a 90-degree angle to the X-axis and will be shooting out the left rendezvous window via a mirror assembly.

During rendezvous maneuvers with the S-IVB, the COAS can be used for alignment.

CREWMAN OPTICAL ALIGNMENT SIGHT (COAS)

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When the TV camera is mounted on the girth shelf for shooting out the right rendezvous window parallel to the X-axis, the COAS will be used for alignment. The COAS can also be used for backup for re-entry alignment and manual thrust vector control.

6.4      SPACE SUIT ASSEMBLY (GFP).

The space suit assembly (SSA) provides crewmembers with protective clothing and atmosphere for spacecraft command module environment. The assembly consists of a constant wear garment (CWG) and pressure garment assembly (PGA). For operational purposes, additional equipment is needed, such as communications and oxygen hoses. The equipment will be described in the two suit conditions: OFF and ON.

6.4.1    SPACE SUIT OFF OR SHIRTSLEEVE ENVIRONMENT.

During earth orbit, normal conditions (nondynamic) will allow the astronauts to remove the pressure garment assembly. The astronauts will wear an undergarment called the constant wear garment (CWG), a part of the space suit assembly. For communications, they will don a personal communications soft hat, connect it to a CWG adapter, and connect the adapter to an electrical umbilical which connects to the audio center.

6.4.1.1   Constant Wear Garment (CWG) (GFP).

The CWG (figure 6-5) is a one-piece, synthetic fabric garment for oxygen compatibility. It will be long sleeved or short sleeved. The short sleeve CWG has sleeve stiffeners. There are also pockets to hold radiation dosimeters. Around the mid-section are pockets for biomed preamplifiers. There are one or two cloth tabs (1 inch) near the chest to attach the cobra cable clip. An opening at the crotch is for urination and the rear opening is for defecation. A zipper up the chest allows easy donning and doffing.

The CWG can be worn for 6 to 7 days; therefore, a change will be needed. Each astronaut will wear a CWG under the pressure garment assembly. Three CWG's will be stowed in the left-hand equipment bay compartment CONSTANT WEAR GARMENT SANDALS. In the same compartment, three flight coveralls, one for each astronaut and three pair of weightless sandals, will be stowed.

6.4.1.2   Flight Coveralls (GFP).

Three flight coveralls will be stowed in the CHEB compartment, marked "CONSTANT WEAR GARMENT," for use while in shirtsleeve environment. The coveralls will be worn over the CWG, and will aid in keeping the CWG clean and the crewman warm.

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SPACE SUIT ASSEMBLY (GFP)

CREW PERSONAL EQUIPMENT

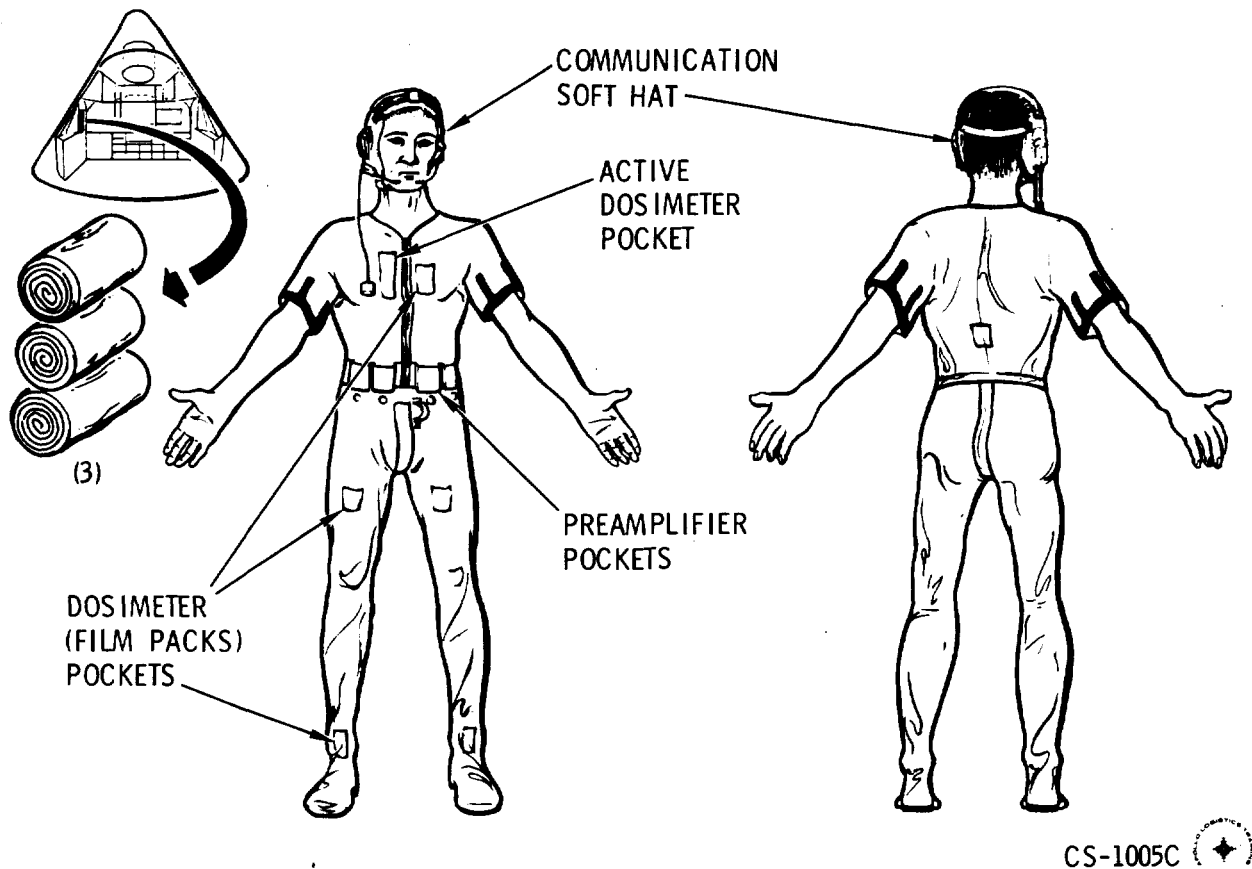


Figure 6-5. Constant Wear Garment (CWG)

6.4.1.3 Communications Soft Hat (GFP).

The personal communications carrier is a soft hat which supports communications equipment: redundant microphone/earphone sets and a connection to the audio center.

The microphones (voice tubes) have two positions: using and stowed. The stowed position is butted toward the forward edge of the helmet. The using position is in front of the mouth. Only one microphone needs to be used. The earphones will be in place over both ears all the time.

Three communications carriers will be stowed at launch and entry in the PGA helmet stowage bags on the aft bulkhead.

Three Lightweight Headsets will be evaluated during the mission and will share the soft hat stowage in the PGA helmet stowage bags.

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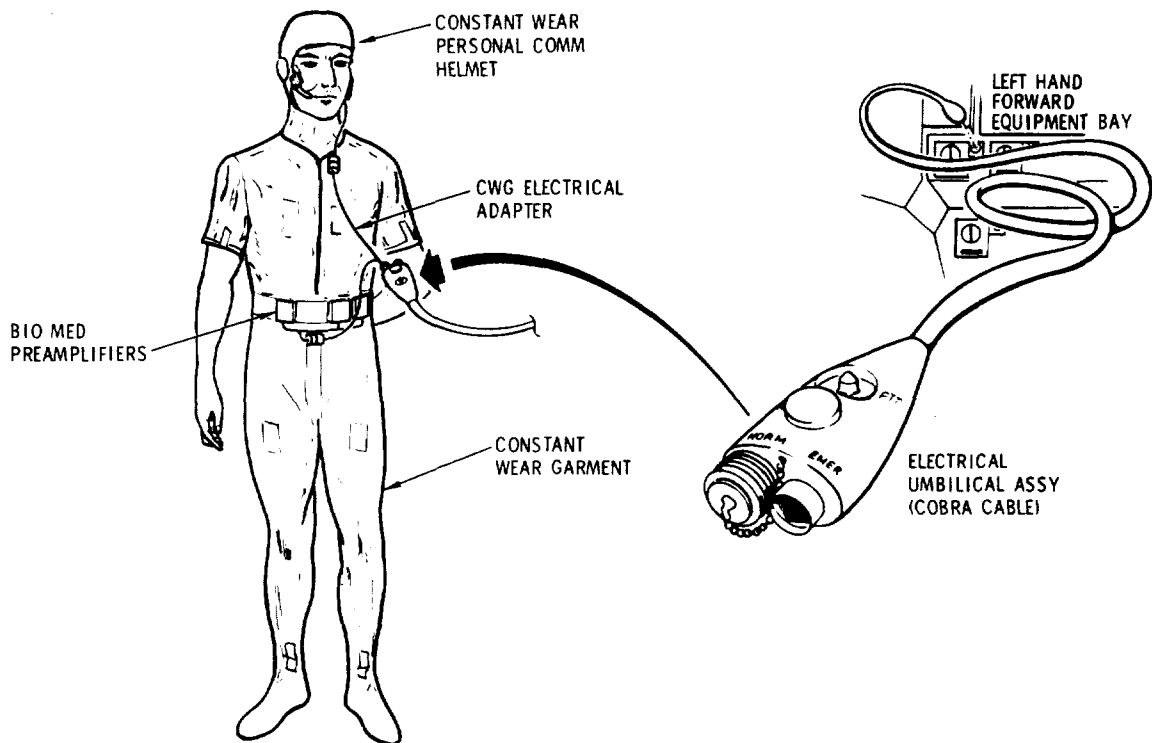
CREW PERSONAL EQUIPMENT

6.4.1.4 Constant Wear Garment Electrical Adapter (CFE).

The function of the CWG adapter (figure 6-6) is to transmit the communications hat signals and the biomedical harness signals to the electrical umbilical or cobra cable.

The CWG adapter is a 37-pin connector which connects to the 21-socket connector from the communications soft hat. The nine-pin connector mates with the nine-socket connector of the biomedical harness connector.

Three CWG adapters will be required if all astronauts go shirtsleeve simultaneously. The three adapters will be stowed in the RHEB in a compartment marked ELECTRICAL ADAPTERS. The CWG adapter will time-share the compartment with three PGA adapters.



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Figure 6-6. Personal Communications Equipment Connection, Block I (CWG)

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6.4.1.5      Electrical Umbilical "Sleep" Adapter.

Two electrical umbilical "sleep" adapters will be stowed in the RHEB compartment marked ELECTRICAL ADAPTERS. The purpose of the "sleep" adapters is to eliminate voice communication signals passing through the caution/warning system, thus enabling uninterrupted sleep for two crewmen. The adapter, connected between the cobra cable and the CWG or PGA adapter, will play a pianissimo version of "Brahms Lullaby."

6.4.2      SPACE SUIT ON ENVIRONMENT.

6.4.2.1      PGA Unpressurized or Ventilated.

During launch, boost, entry, descent, and landing phases of the mission, the crew will be required to be suited. The crew will be fully suited but in the unpressurized or ventilated condition. That is, the cabin pressure will be 5 psi and the differential pressure of the suit will be a plus 2 inches of water or 0.072 psi. This is enough differential pressure to hold the suit comfortably away from the body. The oxygen will be flowing from the ECS suit loop, through the oxygen hose into the suit and returning through the return hose to the ECS suit loop. The cabin air is circulated about the cabin by the cabin air fans 1 and 2.

An alternate mode of ventilated usage is with helmet and gloves off, using neck and wrist dams. The gas circulation is the same, except the astronaut breathes cabin oxygen. This mode can only be sustained for 54 man-minutes out of 18 hours (1:20) because the cabin oxygen becomes saturated with water vapor which will condense on the structure. This is not a recommended mode.

6.4.2.2      PGA Pressurized.

The PGA (space suit) will not be pressurized except during an emergency. This condition will exist during a cabin depressurization. If out of the suit, the ECS can maintain 3.5 psi in the cabin for 5 minutes if the hole or leak is less than 1/2 inch in diameter. Therefore, donning the suit must take less than 5 minutes. When the suit is pressurized, the differential pressure will be a plus 3.7 psi in the suit. This condition constrains the body mobility. For this reason, it is normally not desired to be pressurized.

The crew will perform a cabin depressurization to demonstrate confidence in the spacesuit and proper function of the hardware.

6.4.3      PGA DESCRIPTION. (Figure 6-7)

6.4.3.1      PGA Components.

The PGA is a three-piece suit: torso, helmet, and gloves. It is manufactured by Clark Manufacturing Co. of Massachusetts.

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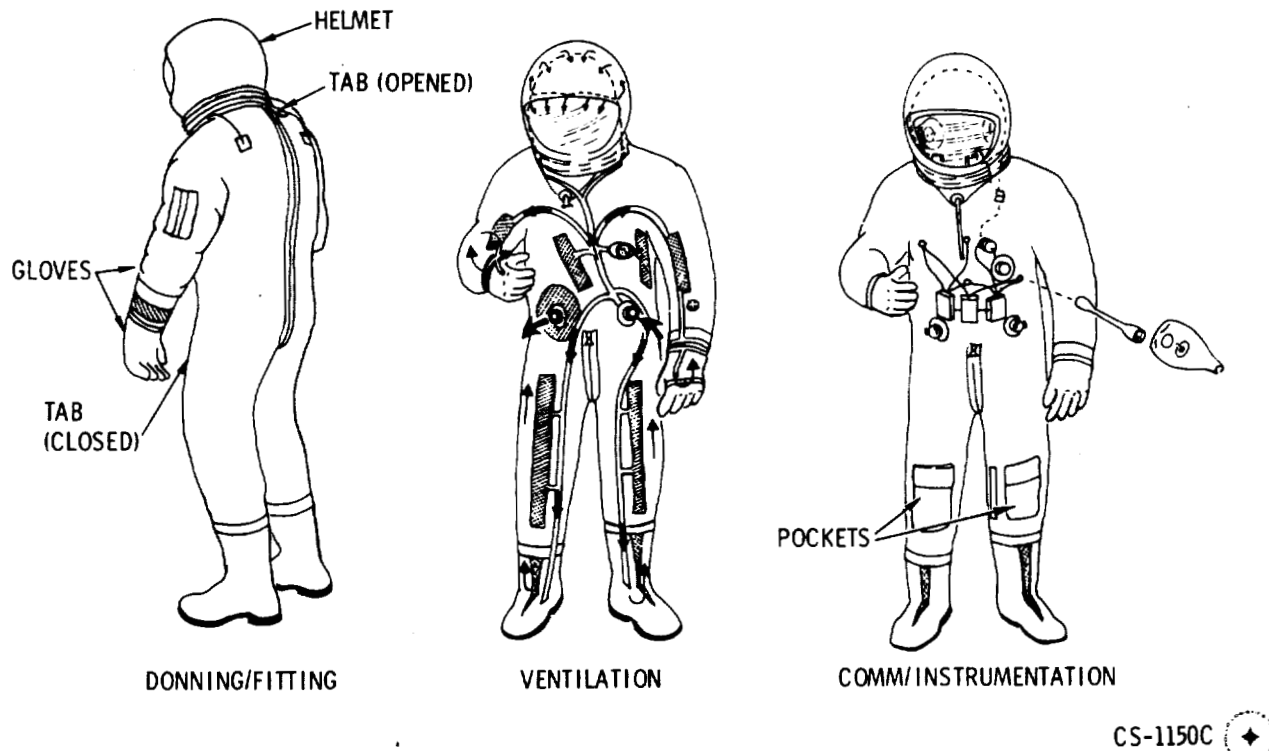


Figure 6-7. Apollo Block I Pressure Garment Assembly

Accessories of the suit are the neck and wrist dams, blood pressure cuffs, and urine collection bag. Operational use of the accessories is optional and will vary in accordance with the mission.

6.4.3.1.1 The Torso and Gloves.

The PGA torso has four layers. From the inside, the first layer is a combination liner and ventilation layer. The ventilation distribution tubes guide incoming oxygen to all extremities. The oxygen also passes through net openings to circulate around the astronaut. The actual cooling takes place as the gas flows from the extremities (higher pressure) to the return (lower pressure) over the CWG. The second layer is a pressure-tight layer, to contain the oxygen or the 3.7-psi operating pressure. The third layer is a restraint layer of strong netting to restrict bulging and enlarging so movement will be unimpaired when pressurized. The last, and outside layer is a protective cover. There is a pressure line from the pressure

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layer (2nd layer) to a surface pressure gauge to allow the astronaut to monitor the pressure. At the waist is an intake connector valve on the left and a return connector valve on the right.

The outside protective layer has pockets on the arms and legs. The arm pockets contain such articles as neck and wrist dams, handkerchiefs, and pencils. The leg pockets contain scissors.

The neck ring is an aluminum ring, and when mated with the helmet, has O-ring seals. Cables are attached to the neck ring to hold it down when pressurized.

The boots are attached to the legs by laces and are not airtight. A sock from the leg fits into the boot and is airtight. The boots will not be removed during the mission.

The gloves are attached to the arms with a ball race lock and are sealed with O-rings.

A zipper runs from the navel, underneath the crotch, and up the spine to the neck ring. The tab is by the navel when sealed (closed) and by the neck ring when opened. To assist the one-man donning, the tab has a 6- to 10-inch lanyard attached to it. The suit has the capability of one-man donning in less than 5 minutes. It can be donned by having the helmet and gloves attached or attaching them after donning the torso.

The communication and biomedical cables exit through a 61-pin connection at the left breast.

6.4.3.1.2 The Helmet.

The helmet is a plastic shell. It has a liner inside, ear cushions with earphones, and two microphones. On the outside, a visor is pivoted at the ears. A visor protective cover of thin plastic (Cycloc) covers the top of the helmet. A ring seal is at the neck. It will set in the torso neck ring and is held in place by a clamp.

To pressurize the suit, the visor (or faceplate) must be closed. It is rotated down across the face and presses against a seal, and is held in position by a clamp-latch.

6.4.3.1.3 Neck and Wrist Dams.

The primary function of the dams is postlanding sealing of the PGA during water activity.

The dams are wide rubber bands. The neck dam fits over the torso neck ring and around the neck. This keeps the sea water out of the suit. The helmet must be removed. When the gloves are removed, the wrist dams seal the wrists and the crewman will float in the torso.

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An optional dam use during the mission would be to cool the body while in the suit with the gloves and helmet off. This is restricted to a short period of time as the crewmans respiration would produce an excessive CO<sub>2</sub> concentration. The comm helmet will be used for communications during this period.

6.4.3.1.4 Urine Collection Device (GFP).

During the standby, hold, launch, and boost phases, the crewman will be suited. A continuous suited period of 3 to 6 hours can be experienced so provisions must be made to urinate within the PGA.

The function of the urine collection bag is to collect and store 1200 cc of urine. There is an external catheter (roll-on) connected to the bag. The bag fits around the crotch and hips and is held into place by Velcro attached to Velcro on the CWG.

When mission operations permit, the suit is unzipped and the urine bag is removed. A valve on the bag will connect to the waste management system, and the urine will be dumped overboard.

6.5 PGA STOWAGE.

6.5.1 TORSO AND GLOVE STOWAGE.

The gloves will be left attached to the torso and stowed together. The PGA helmets will be stowed separately. The suit stowage bag is made of sage green, nylon cloth, 36 inches long, 20 inches wide, and can be expanded from 3 to 12 inches high. It has an aluminum rod frame to maintain the form. A partition separates the bag into two compartments. On the top are flaps held closed with Velcro. Three strips of Velcro loop are on the bottom to anchor the bag on three strips of Velcro hook on the aft bulkhead.

The two-PGA stowage area is beneath the commander's couch (left) on the aft bulkhead. An additional stowage bag is located beneath the head of the pilot on the aft bulkhead near the hatch between the LiOH cartridge stowage boxes and the sidewall. The suit stowage bag is similar to the two-suit bag.

6.5.2 HELMET STOWAGE.

The PGA helmets are stowed only during nondynamic periods, or zero g. Three helmet mid-course stowage bags are provided. The bags (GFP) are located on the aft bulkhead under the center couch.

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6.6        PGA CONNECTING EQUIPMENT.

6.6.1      PRESSURE GARMENT ASSEMBLY (PGA) ELECTRICAL ADAPTER (GFP).

The PGA electrical adapter provides interface between the PGA and the cobra cable since the connectors are not compatible.

The PGA adapter is 18 inches in length with a suit interface of a 61-socket connector and the cobra cable interface with a 37-pin connector. There are three adapters.

When the suits are removed and stowed, the PGA adapters will be disconnected from the suit and stowed. They will replace the CWG adapters in the ELECTRICAL ADAPTER stowage compartment in the RHEB.

6.6.2      OXYGEN HOSE (UMBILICAL) (GFP). (Figure 6-8)

The function of the oxygen hose is to interconnect the PGA and the CM ECS.

The oxygen hose is a dual hose, each hose having an inside diameter of 1.25 inches and made of silicon rubber with spiraling steel wire reinforcement.

The ECS end has a double D connector while the suit end splits the hoses about 15 inches from the end. Each hose has an elbow nozzle to connect to the suit.

There are two hoses: one 72 inches long and one 81 inches long. A nylon strap is bonded approximately every 12 inches to restrain the cobra cable to the hose during suit operations.

The double D connector on the ECS end remains connected during the mission. The hose is routed behind the MDC and held in place by tie-down straps. When disconnected from the suits, the ends are routed from the rear of the MDC to the forward bulkhead and strapped. To prevent the incoming oxygen from being sucked into the return side and not into the cabin, the return nozzle will be capped with the oxygen hose return cap, which is attached to the hose with a lanyard.

6.7        CREW COUCHES.

The crew couches support the crew during acceleration and maneuvers up to 30 g's forward, 30 g's aft, 18 g's up and down, and 15 g's laterally.

The spacecraft contains unitized crew couches integrally bolted together in a unit structure.

The couches are designated one of three ways. Structurally, they are left, center, and right. By crew positions, they are 1, 2, or 3 or commander, senior pilot, and pilot (left to right).

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PGA CONNECTING EQUIPMENT—CREW COUCHES

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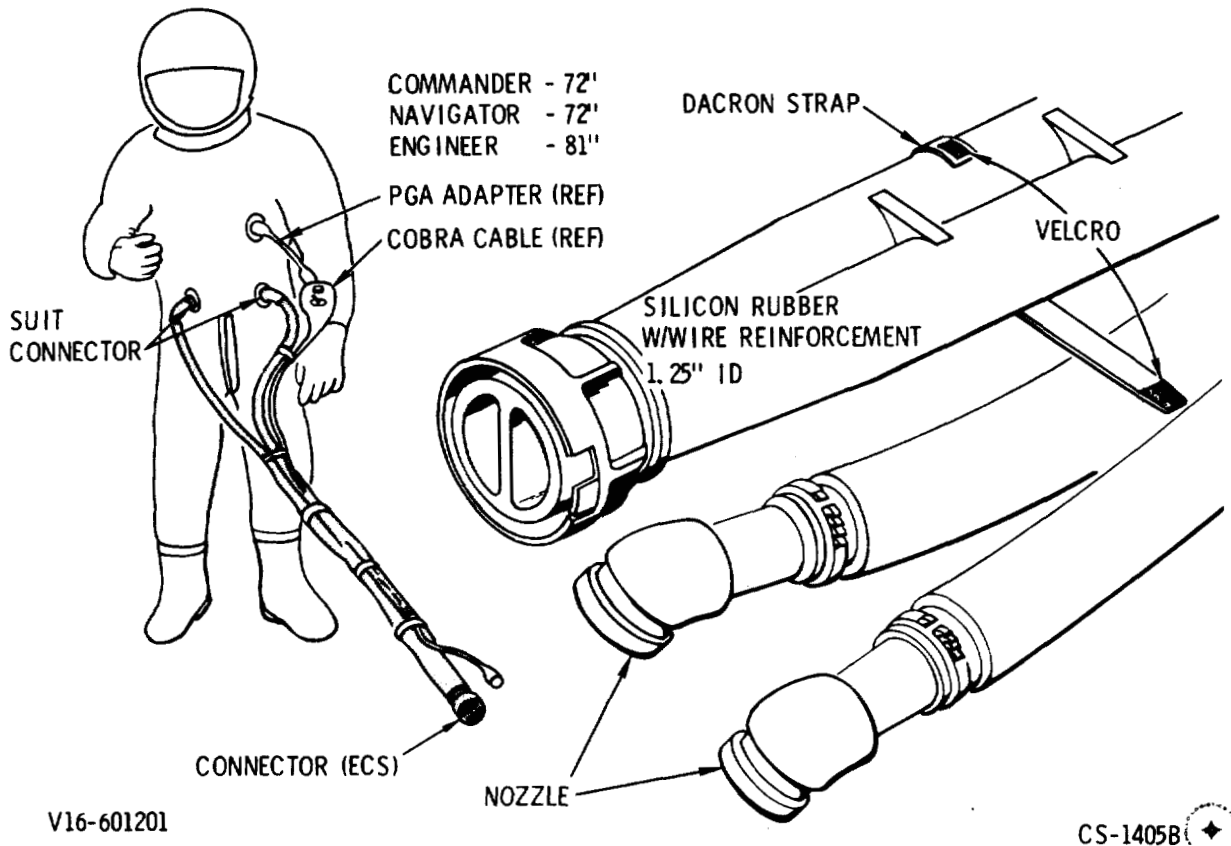


Figure 6-8. O<sub>2</sub> Umbilical Hose Assembly, Block I

6.7.1 CREW COUCH STRUCTURE.

The crew couch structure consists of three crew couches: the left, center, and right (figure 6-9). It is fabricated of aluminum and weighs approximately 400 pounds. The left and right couches are identical. The center couch connects the left and right couch into a single unified structure.

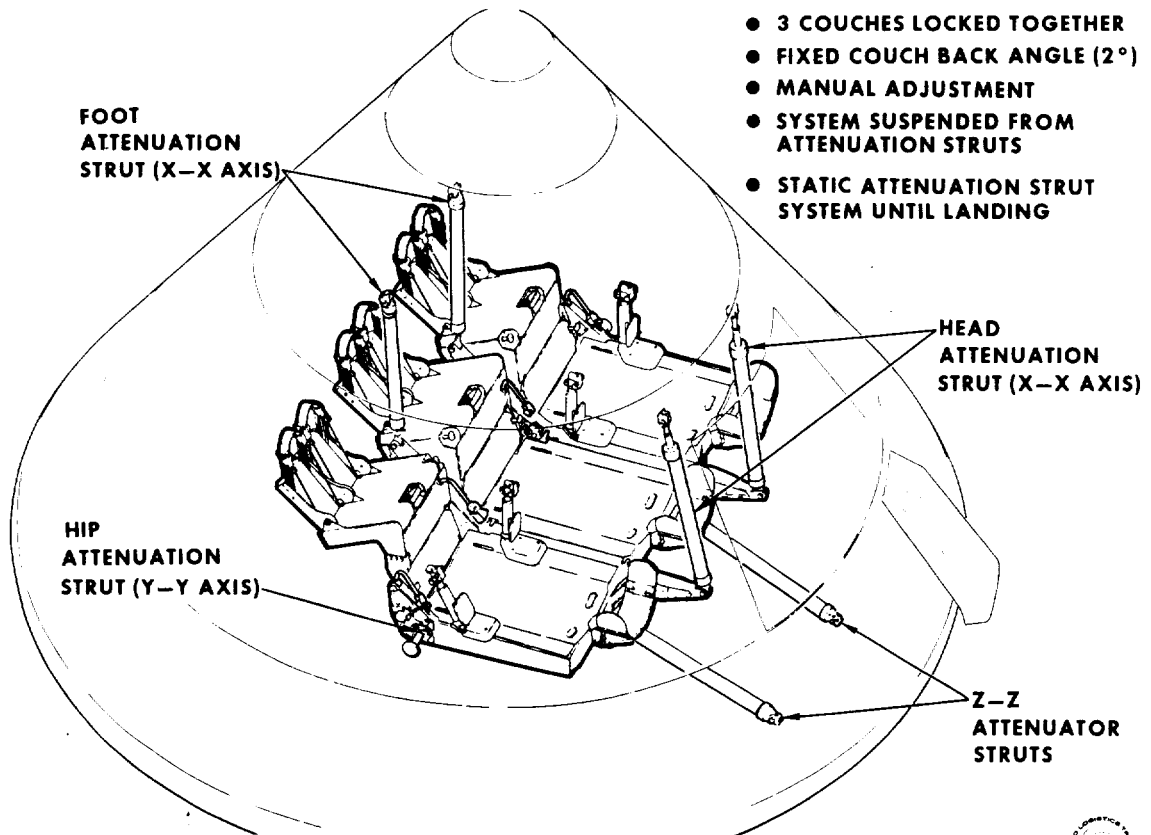
The couch structure, in a one-g environment, is supported by the impact attenuation struts: the four X-X struts from the forward bulkhead, the two Z-Z struts from the aft ring, and the two Y-Y struts in compression against the side panels. The X-X and Z-Z struts connect to the crew couch structure at the left and right couch main side beams.

The left and right couches are capable of the 170-degree position but will not be placed in that position because of equipment interference beneath those couches.

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Figure 6-9. Crew Couch Installation

The additional LEB access/docking position will be used during orbit to gain room near the LEB. The seat pan angle remains 96 degrees while the couch structure (all couches) moves 6.5 inches toward the hatch.

6.7.2 CREW COUCH POSITIONS. (Figure 6-10)

6.7.2.1 Occupied Positions.

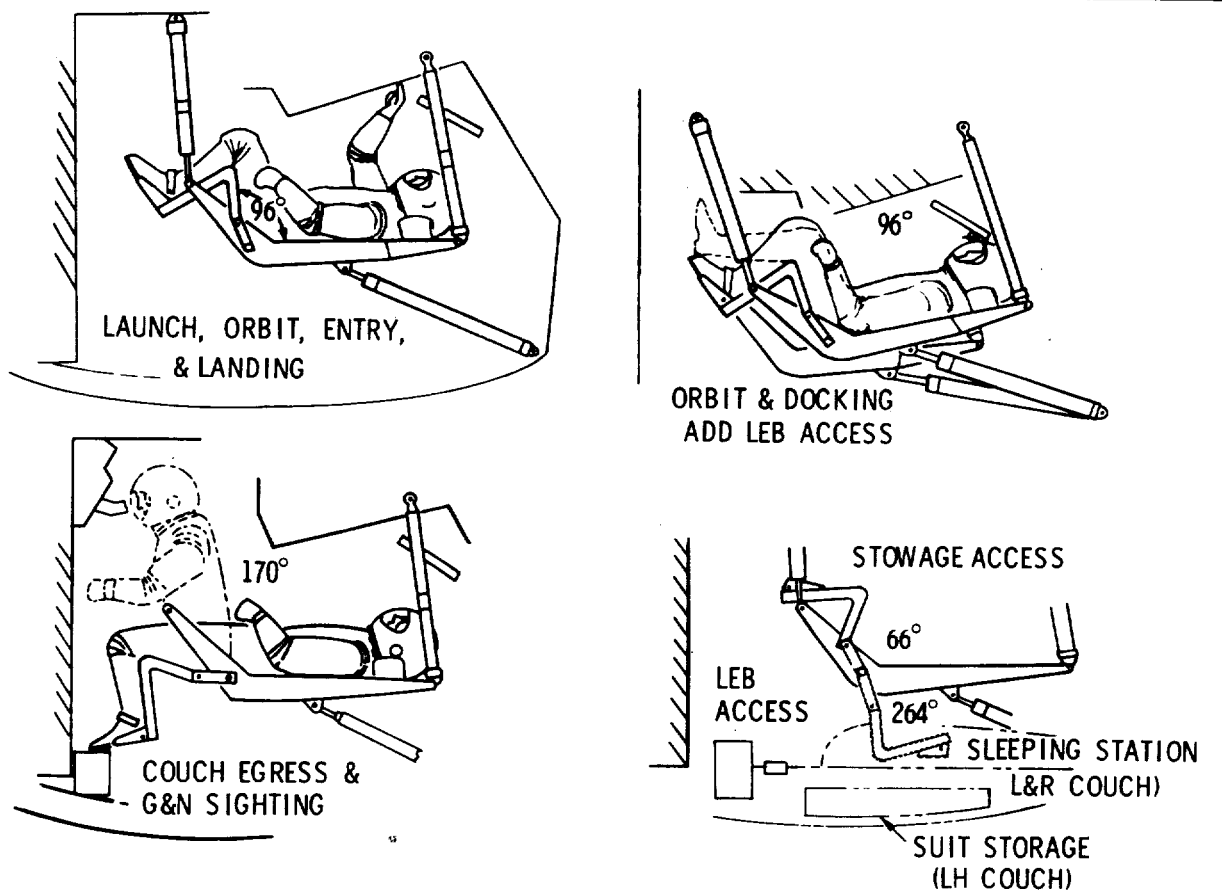
The most utilized position is the 96-degree position assumed for the launch, orbit, and entry phase. For a 50 percentile crewman, the hip angle is 108 degrees and very easy to assume. It gives maximum support to the body during high g loads.

The 170-degree or flat out position is used primarily for egressing from the center couch. All egressing to the LEB will be from the center couch. For this reason, the lower armrests are removed and stowed,

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Figure 6-10. Crew Couch Mission Positions and Seat Angles, Block I

making easy egress from right and left couches into the center couch. Another use of the 170-degree position is G&N sighting. The 50 percentile crewman can position himself on the seat pan with his feet in the footrests and sight through the G&N eyepiece.

#### 6.7.2.2 Unoccupied Positions.

The 66-degree seat pan angle position is used primarily for right and left equipment bay stowage access.

The 264-degree position necessitates rotating the seat pan under the backrest. This will clear the LEB area for maintenance activities. Due to restricted clearance beneath the left and right couches, this position is restricted to the center couch only. During use of the fecal canister, this is the desirable seat pan angle.

#### CREW COUCHES



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6.7.3 CREW COUCH COMPONENT DESCRIPTION. (Figure 6-11)

The crew couches are basically the same and the modular components interchangeable. The backrest assemblies differ the most because of the docking position mechanism in the center couch.

6.7.3.1 Headrest.

The headrest is constructed of honeycomb aluminum and has folding tips. It is padded on the inside and both sides of the tips. During maneuvers requiring PGA helmet restraint, the tips are left extended. For orbit and zero g, the tips are folded, affording freedom of movement for nominal visibility.

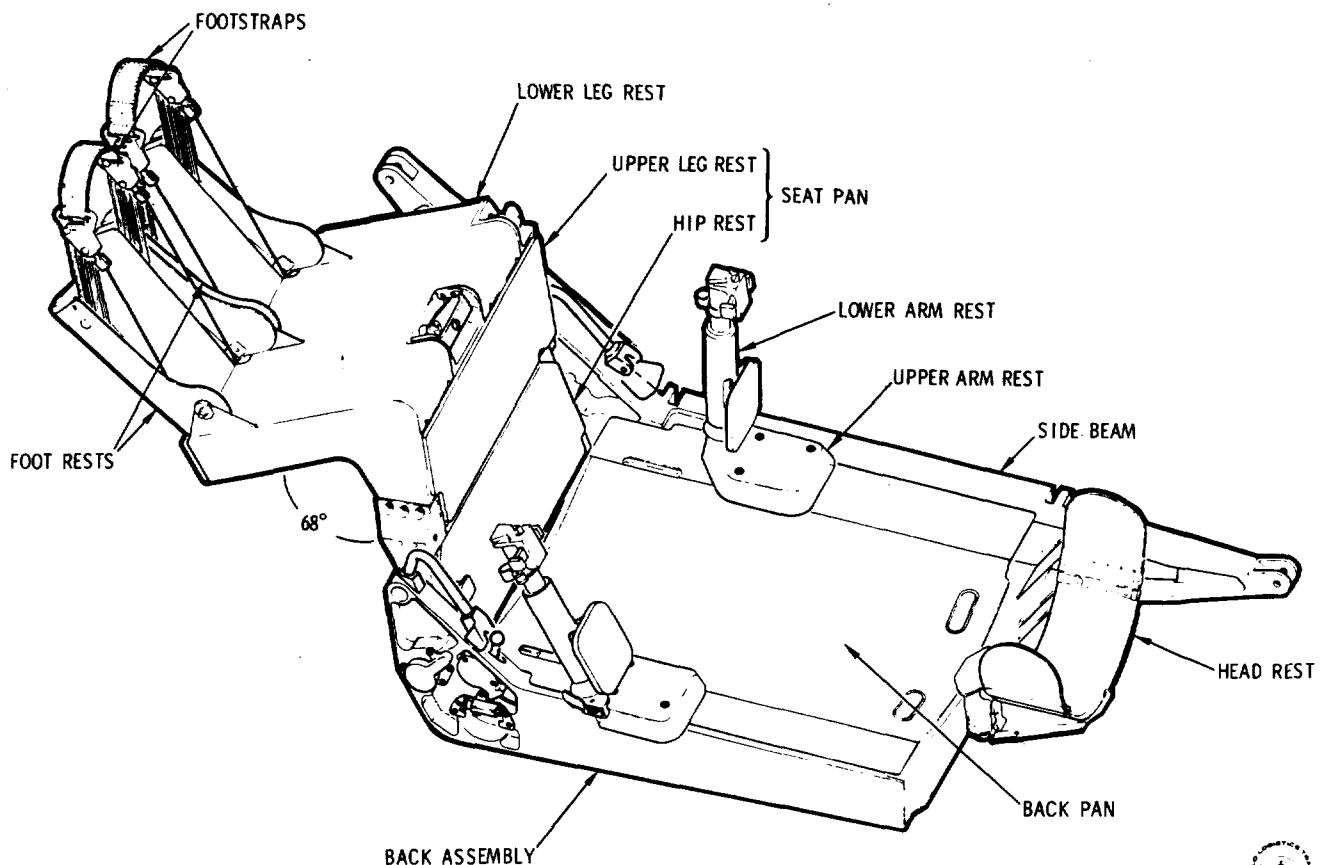


Figure 6-11. Left-Hand Couch Assembly (96-Degree Position)

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The headrest has a 3-inch longitudinal movement for adjustment to crewman torso length. The headrest and support will fold under the couch for purposes of accessibility and ingress to the couches.

6.7.3.2 Backrest.

The backrest is constructed of ribs and beams covered with aluminum sheet and is 32 inches long and 22 inches wide. The left and right couch back pans are attached to the integral side beams, the inboard beam of which is 56 inches long and the primary structural member of the couch support.

The backrest assembly is contoured and contains the takeup reel system for the shoulder straps. The back pan is padded in the areas of crewman contact.

6.7.3.3 Armrests.

The armrests attach to the forward surface of the backrest and are adjustable. They consist of an upper and lower armrest. The upper armrest can be adjusted for length of arm and torso.

The lower armrest inserts into and is supported by the upper armrest at an angle of 90 degrees. It is secured by a leverized pin device for quick removal. A tubular shaft extends past the rest pad and contains the mounts for the controls. A major function of the armrests is to mount the SCS controls. The left couch left armrest has an adapter mount for both translation controls T1 and T2, and mounts at an angle of 120 degrees. All other armrests (3) mount at an angle of 90 degrees. The left couch right armrest supports a rotation control (R1). The center couch has no armrests.

On the right couch left armrest is a fitting to which the other rotation control (R2) can be attached for use by the center astronaut. By using an adapter, one translation control (T2) can be mounted for use by the right astronaut.

Normally, the right couch right armrest supports the second rotation control (R2). A third position for the rotation control (R2) is attached to the LEB G&N panel for use during navigational sightings.

6.7.3.4 Seat Pan and Footrest.

The seat pan and footrest has three components: the hiprest, legrest, and footrests.

The hiprest and upper legrest functions as a seat or seat pan. The lower legrest supports the lower legs, and the footrests support and restrain the feet. The hiprest makes an angle of about 170 degrees with the upper legrest, forming the seat pan. There are two pivot points: one at

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the aft of the hiprest, and the other where the hiprest and legrest intersect. Part of the mechanism for positioning the seat angles at 96, 170, and 264 degrees is housed in the hiprest.

The lower legrest houses the mechanism for positioning the seat in the 66-degree angle and tightening or loosening of the footstraps. The upper legrest to lower legrest angle is fixed at 68 degrees. The footrests pivot so they can fold parallel to the lower legrest. Footstrap rotation bars are spring-loaded to the release position and are pulled to the restraint position by cables. The cables run to a reel that can be locked or released by a control in the lower legrest.

6.7.3.5 Crew Couch Pads.

The following portions of the couches have pads: headrest, back pan, armrests, and seat pan.

The padding is a triloc material 3/16-inch thick. It is structured of woven dacron wire-like fibers in a low-density pattern giving good ventilation.

The back pan and seat pan pads are composed of three layers of triloc covered with nylon netting, making approximately 1/2 inch of padding.

The armrest and headrest pads are 3/16-inch-thick layers between nylon netting covers.

The pads are attached to the metal surfaces with Velcro strips and can be removed during the mission if the need arises.

6.7.4 MECHANICAL ADJUSTMENTS. (Figure 6-12)

6.7.4.1 Headrest Adjustments.

To adjust the headrest for crewman height, turn the adjustment with the tool set 4-inch CPS driver. It has a 7/32-inch hex drive.

The headrest is folded down by pulling the headrest lock headward. The headrest is spring-loaded to the stowed (down) position so it should be restrained by the hand. To bring it up, pull with the hand; pull headrest lock handle back to clear the hook, position headrest in the normal position, and push the lock handle footward.

6.7.4.2 Armrest Adjustments.

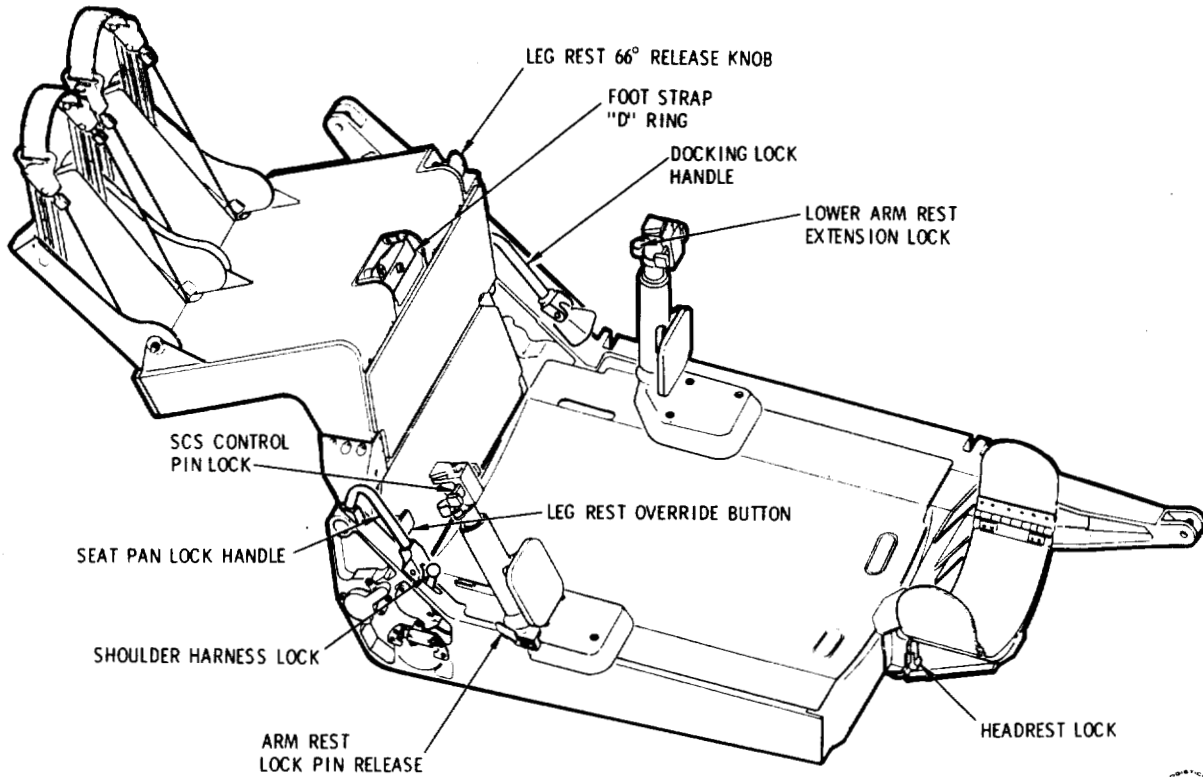
The lower armrests are removed by pulling the armrest lockpin release outward to pull the pin, and then pulling the armrest upward to remove. The left couch right armrest and the right couch left armrest are stowed on the couch side beams by Velcro seats and straps.

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Figure 6-12. LH Crew Couch Operating Mechanisms, Block I

To attach SCS controls, push the SCS control pinlock to the left; slide the control on the dovetail; and push the lock to the right locking a retention pin.

The lower armrest can be extended by rotating the extension lock toward the left, extending the armrest and locking into position by pushing the lock to the right.

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6.7.4.3 Seat Pan Adjustment Directions.

SPLH = Seat Pan  
Lock Handle

LRRK = Legrest  
Release Knob

LROB = Legrest Override  
Pushbutton

From (Deg)	To (Deg)	Procedure	Remarks
A 96	170	<ol style="list-style-type: none"> <li>1. Lift the SPLH and push with feet.</li> <li>2. Release the SPLH; continue pushing with feet until seat stops at 170°.</li> </ol>	<ol style="list-style-type: none"> <li>1. Key locking the leg pan will disengage.</li> <li>2. Key on pivot cylinder will engage side beam keyway.</li> </ol>
170	96	<ol style="list-style-type: none"> <li>1. Lift the SPLH and pull with feet.</li> <li>2. Continue lifting SPLH, pulling with feet until seat stops at 96°, release SPLH.</li> </ol>	<ol style="list-style-type: none"> <li>1. Key on pivot cylinder will disengage.</li> <li>2. Key on pivot cylinder will engage side beam keyway.</li> </ol>
B 96	264	<ol style="list-style-type: none"> <li>1. Lift SPLH and rotate downward.</li> <li>2. Continue to lift SPLH passing through 170° position.</li> <li>3. Release SPLH and continue rotating until seat stops at 264°.</li> </ol>	<ol style="list-style-type: none"> <li>1. Key locking leg pan will disengage.</li> <li>2. Maintains the leg pan pivot key in disengaged position.</li> <li>3. Key on pivot cylinder will engage in 264° position slot.</li> </ol>
264	96	<ol style="list-style-type: none"> <li>1. Lift SPLH and rotate seat toward 170°/96° position.</li> <li>2. Continue to lift SPLH, passing through 170° position.</li> <li>3. Rotate to 96° position and release SPLH.</li> </ol>	<ol style="list-style-type: none"> <li>1. Leg pan pivot key disengages allowing rotation.</li> <li>2. Leg pan pivot key maintained in disengaged position.</li> <li>3. Leg pan point pivot key will engage 96° position slot.</li> </ol>
C 96	66	<ol style="list-style-type: none"> <li>1. Pull up with feet until 66° latch engages the side beam.</li> </ol>	<ol style="list-style-type: none"> <li>1. Disengages seat to hip-rest detent. 66° latch will drop in slot on beams and catch.</li> </ol>
66	96	<ol style="list-style-type: none"> <li>1. Press the LRRK with feet until 96° position is reached.</li> </ol>	<ol style="list-style-type: none"> <li>1. 66° catch disengages. On reaching 96° position, detent will engage.</li> </ol>

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6.7.4.4      Footrest and Footstrap Adjustments.

The footstraps are controlled by a footstrap D-ring (FSDR) between the astronaut's knees. The D-ring is connected to a cable that runs through a tube to a drum-axle-drum mechanism. By pulling on the D-ring and rotating the drum and axle, cables pull the footstraps to the restrained position. The drums have ratchets that lock the footstraps in position and retain the feet in the footrest. To release the footstraps, the FSDR is pressed, forcing the connecting tube to disengage the ratchet and release the footstraps.

6.7.4.5      D-Ring Handle Extension.

The D-ring handle can be reached easily while the PGA is unpressurized. However, when pressurized, the PGA slightly restricts the 90 percentile crewman from reaching the D-ring, thus making it difficult to lock or free the feet. The D-ring extension has been designed to connect to the D-ring handle. The extension has a 7/16-inch hex shaft to insert into the D-ring handle and control it (paragraph 6.10.10). It has a ball-lock feature to connect to the D-ring. The D-ring extension will be accessible on the right girth shelf.

6.7.4.6      Docking Position Adjustment.

The mechanism that releases the lock which allows the couch structure to slide to the docking position is located in the backrest of the center couch; however, the docking lock handle is on the right side beam of the left couch.

The forward end of the Z-Z struts attaches to the couch by a slide that runs in tracks in the side beams. A lever-lock device (finger latch) locks the slide in two positions: normal and docking. The lever-lock is spring loaded in the lock position. The docking lock handle (DLH) disengages the lever-lock only while the DLH is lifted. The couch structure must be pulled to the docking position by the center astronaut pulling on hand holds located on the side hatch.

When transversing to the docking position, the seats remain in the 96-degree position. The left crewman then lifts the DLH and the center crewman grabs a handhold and pulls the couches toward the side hatch. After movement, the DLH can be released. When the couches have moved approximately 6.5 inches, the lever-locks will drop into slots, locking the couches in place.

To return to the couch normal position, the DLH is lifted and the couches are pushed toward the LEB. The DLH is released and the lever-locks will drop into slots when in position.

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6.7.4.7     Shoulder Strap Adjustment.

The shoulder strap takeup reels are on the couch backrest. They allow 10 inches of play and are locked by the shoulder strap lock on the left sides of the couches. A headward pull will unlock the shoulder straps, and a forward and down push will lock the shoulder straps.

6.8     CREWMAN RESTRAINTS.

The crewman restraints provide restraint and physical attachment to the astronauts.

- a. In the couches during launch, weightless phases, abort, entry, and landing
- b. During weightless periods while performing tasks out of the crew couch
- c. While in the sleep position
- d. When performing extra vehicular activities

6.8.1     HIGH G-LOAD RESTRAINTS.

6.8.1.1     Crewman Restraint Harness.

There are three restraint harnesses per spacecraft, one for each crewman.

The restraint harness consists of a lap belt and two shoulder straps interfacing the lap belt at the buckle. The harness is permanently attached to the couch and is not removable. The lap belt interfaces straps connected between the seat and back pans. This configuration provides adequate hip support (figure 6-13).

The shoulder straps pass through slots in the upper portion of the back pan and are connected to spring-loaded takeup reels fastened on the underside of the back pan. The takeup reel allows 10 additional inches of strap travel at maximum 10-pound pull. The crewmember can lock or unlock these takeup reels simultaneously by actuating a lever on the side of the couch.

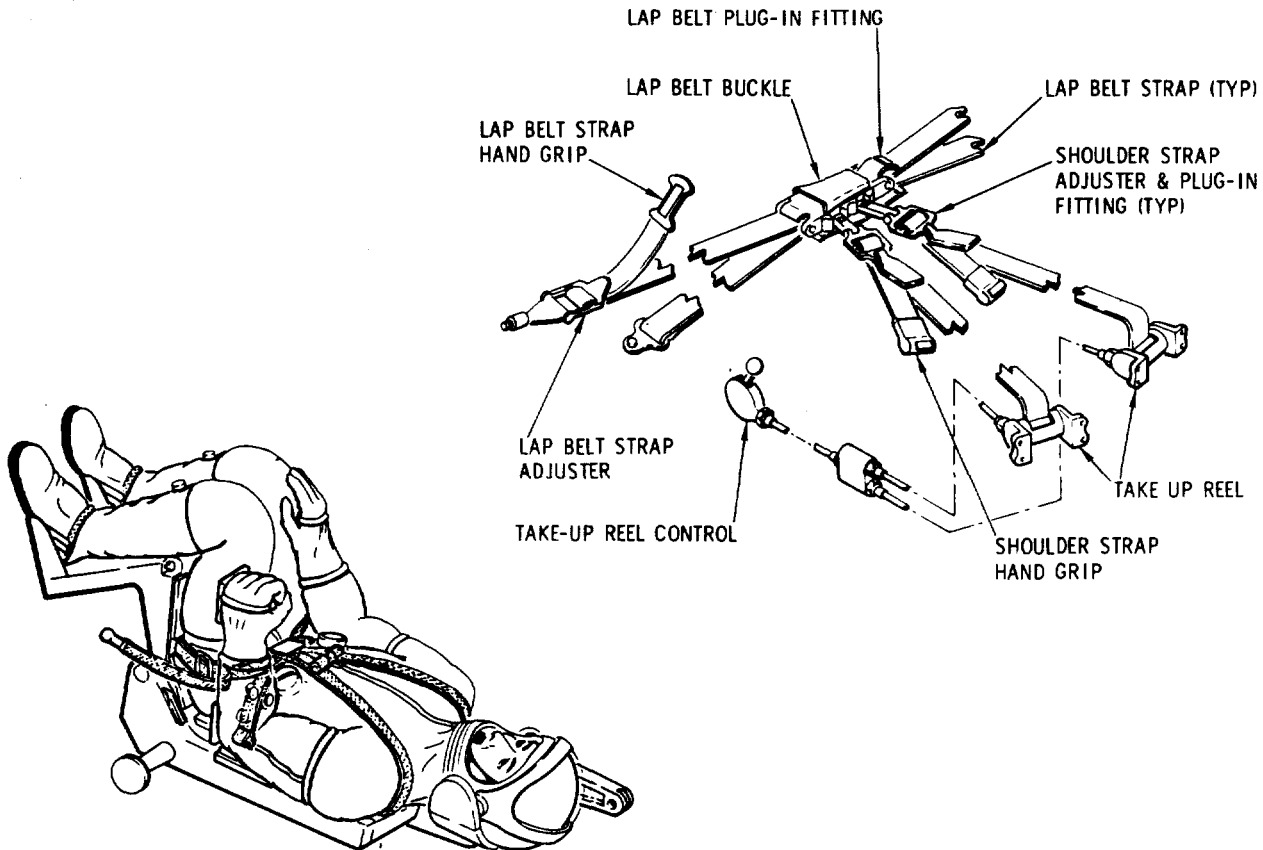
The lap belt buckle is a lever operated, three point release mechanism. By pulling a lever, the shoulder straps and right lap belt strap will be released. The strap ends and buckle are equipped with Velcro patches and may be fastened to mating patches on the couch when not in use. This also prevents the buckles and attachments from floating free during zero g. Each strap can be individually tightened or loosened by the crewman (figure 6-14).

The maximum force on the harness straps will be 3115 pounds at the chests. The straps are dacron, 1-7/8 inches wide, and have a strength of 6000 pounds.

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CREW COUCHES—CREWMAN RESTRAINTS

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CS-Z302 

Figure 6-13. Crewman Restraint Harness Components

The harness will be on and locked during all maneuvers when g loads are expected such as launch, delta V, docking, entry, and landing. Securing in the couch prior to impact will include locking of the foot straps in addition to fastening of the harness. The harness can be tightened and loosened readily by the astronaut.

6.8.1.2 Weightless Restraint.

To assist the crew in egressing from the couch, five hand straps are attached behind the MDC (figure 6-15).

When out of the couch, the astronaut will restrain himself with hand-holds and Velcro foot restraints. Part of the aft bulkhead will be surfaced with Velcro hook material. The astronaut will wear Velcro pile material on the soles and heels of his PGA boots when in the PGA.

CREWMAN RESTRAINTS



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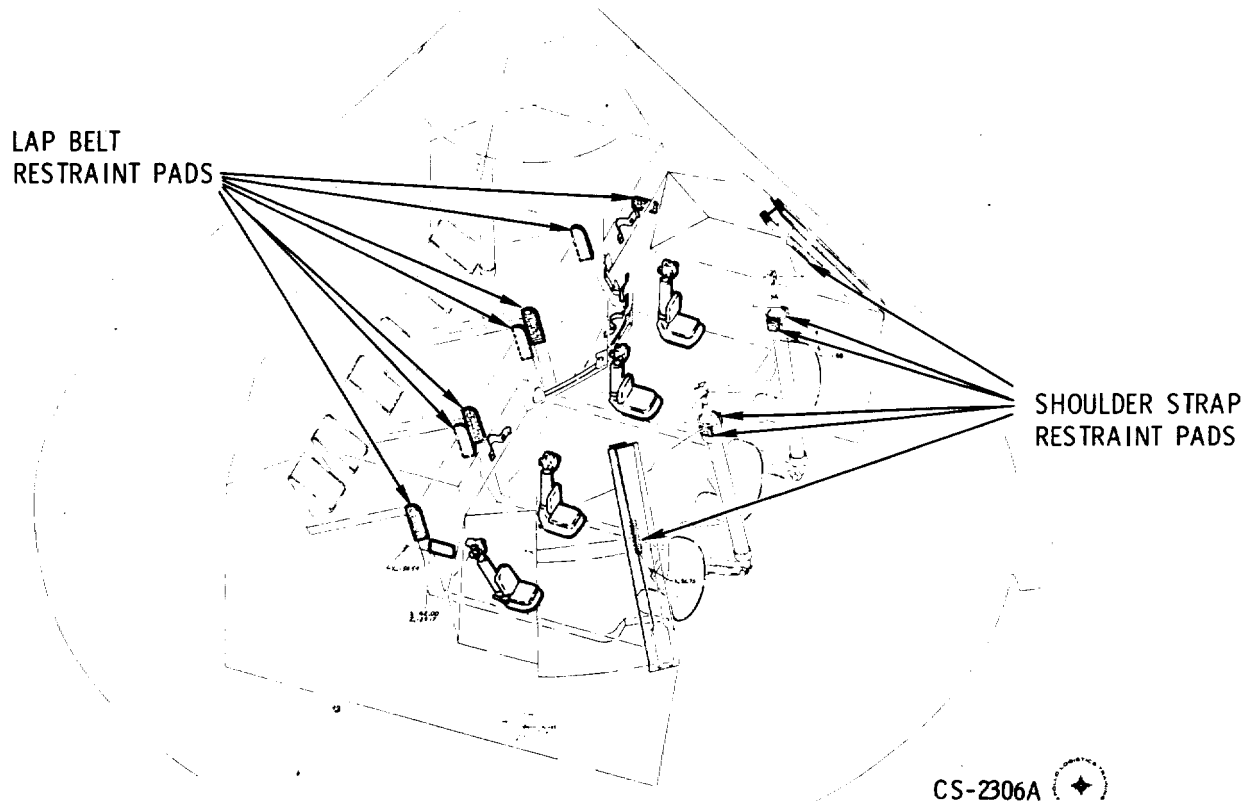


Figure 6-14. Restraint Harness Velcro Restraint Pads

Restraint sandals (figure 6-16) will be worn with the CWG. The sandals are fabricated of a flexible plastic Royalite PR55. Velcro pile material is bonded on the ball and heel of the sole. The sandal is held closed and on the foot by Velcro patches.

There are three pairs of sandals which are stowed in the LHEB with the CWGs and flight coveralls.

6.8.1.3 Guidance and Navigation Station Restraint.

Two positions may be utilized at the G&N station: standing position or center couch G&N position. The astronaut will restrain himself in the standing position by fastening his restraint sandals to the aft bulkhead and using a handhold on the left side of the G&N console.

The astronaut will restrain himself in the center couch at the G&N station by positioning the couch to the 170-degree hip angle and restraining his feet with the couch foot straps.

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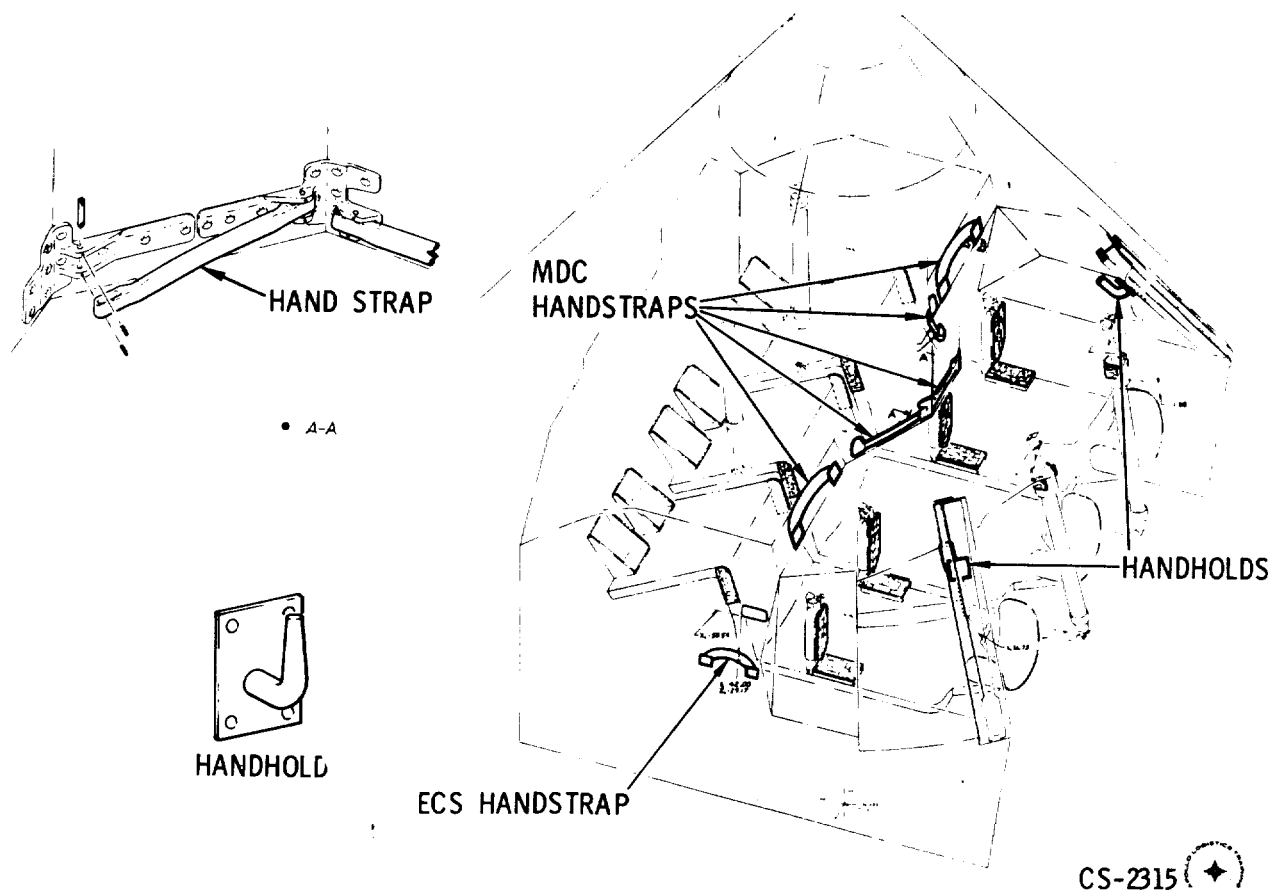


Figure 6-15. CM Interior Handgrips

6.8.1.4 Crewman Sleeping Restraints. (Figure 6-17)

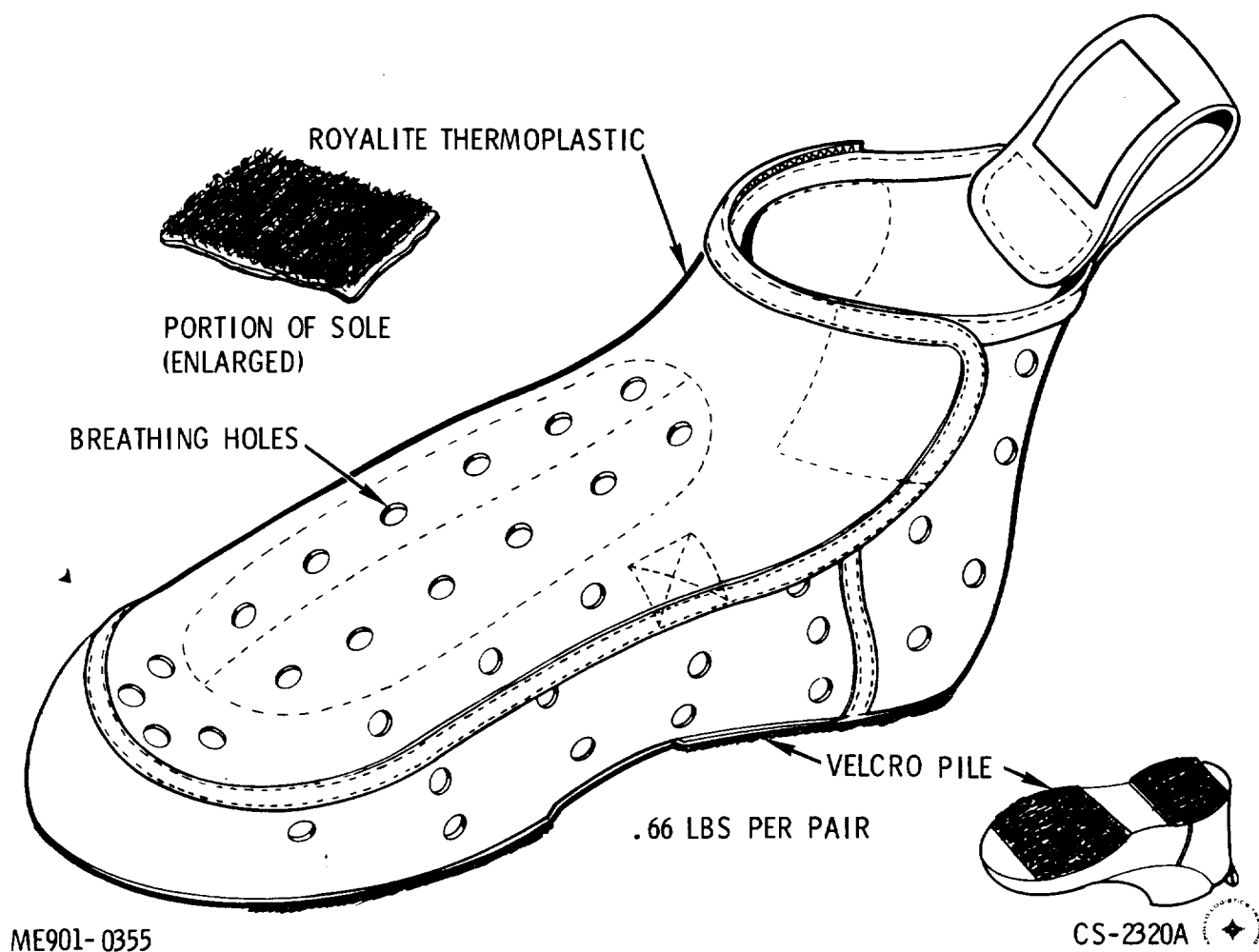
The crewmen sleeping position will be under the left and right couch with the heads toward the hatch. He will be restrained in position by the crewman sleeping restraint.

The restraints (2) are dacron fabric, lightweight, sleeping bags, 64 inches long, with zipper openings for the torso and 7-inch diameter neck openings. They are supported by two longitudinal straps that attach to the LiOH canister storage boxes on one end (LEB) and to the CM inner structure at the other end.

The crewman will occupy the sleeping bag while wearing his CWG and communications soft hat, or lay on top if wearing his PGA. The cobra cable and "sleep" adapter will remain connected. One sleeping restraint will be stowed in each PGA stowage bag during boost and entry.

CREWMAN RESTRAINTS

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ME901-0355

Figure 6-16. Weightless Crewman Restraint Sandal

6.9

FLIGHT DATA FILE (GFP).

The flight data file (figure 6-18) is a mission reference data file that is readily available to the crewman.

The data must be accessible to the commander and pilot in a pressurized suit while constrained in the crew couch. It must be available to the senior pilot at the lower equipment bay.

The flight data file contains checklists, manuals, and charts. The commander's and pilot's data file is stowed in nylon bags and the senior pilot's is stowed in a drawer container.

CREW RESTRAINTS—FLIGHT DATA FILE (GFP)

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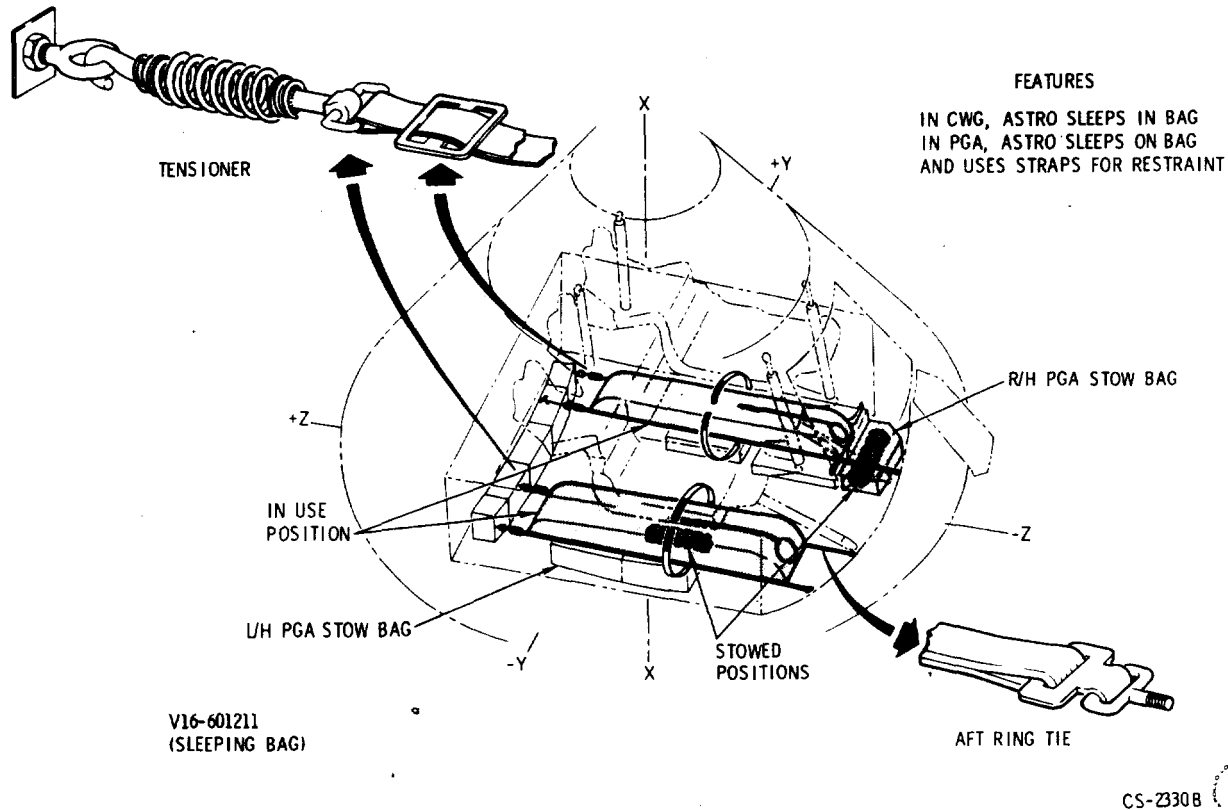


Figure 6-17. Sleeping Position Restraint Configuration

6.9.1 COMMANDER'S FLIGHT DATA FILE.

The commander's flight data file contains a commander's checklist, flight plan, and stowage bag. The stowage bag is nylon cloth material with pouches that close and are retain-closed by Velcro. A flap at the top is lined on the reverse side with Velcro attaching it to its stowage position. It is stowed on the left girth shelf near the commander's left shoulder.

6.9.2 SENIOR PILOT'S FLIGHT DATA FILE.

The senior pilot's data file contains a senior pilot's checklist, mission log and data, and stowage bag. The stowage bag is the same as the commander's except for the nomenclature. It is stowed on the right girth shelf near the senior pilot's left shoulder.

CREWMAN RESTRAINTS—FLIGHT DATA FILE (GFP)

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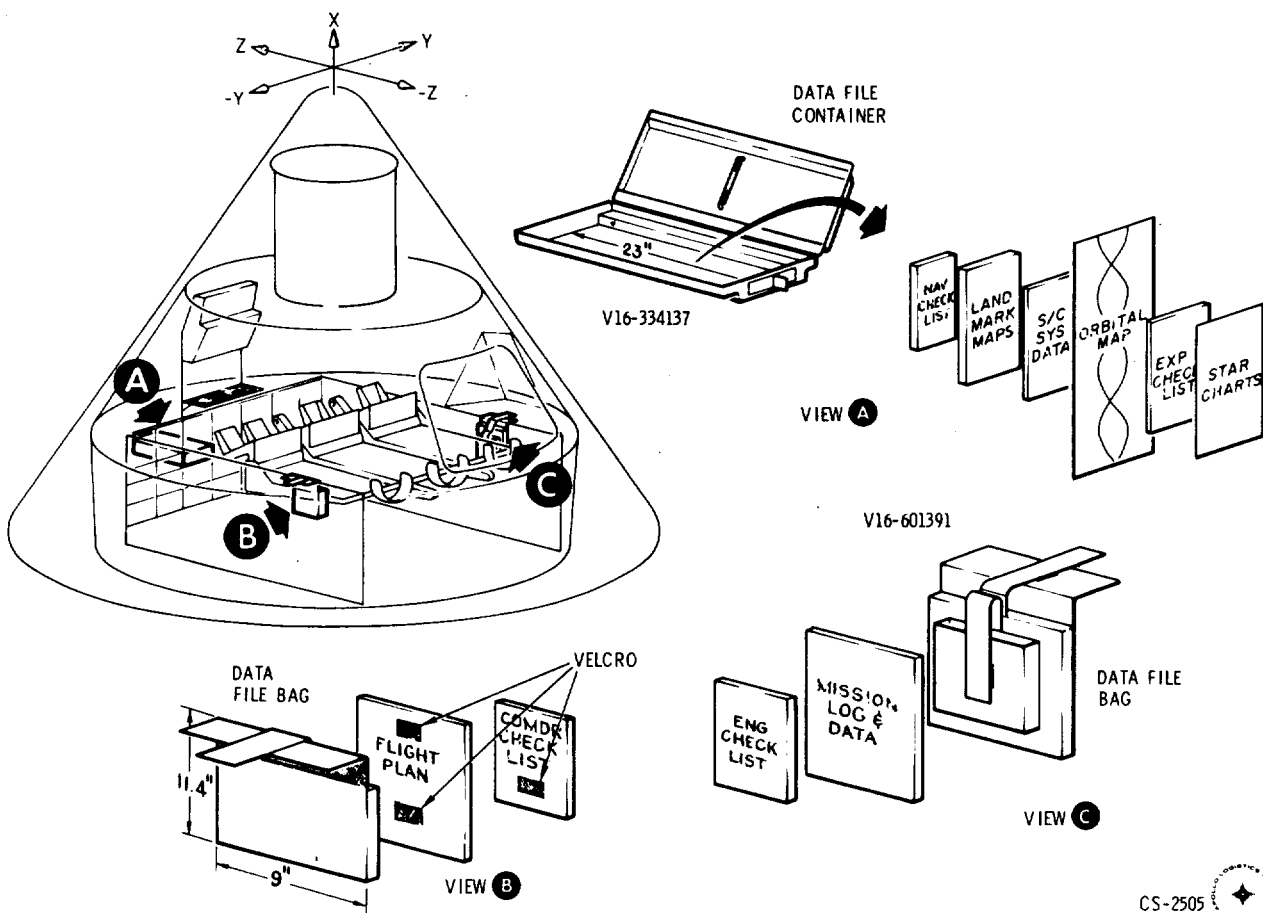


Figure 6-18. Flight Data File Configuration, Block I

6.9.3

PILOT'S FLIGHT DATA FILE.

The pilot's data file contains a pilot's checklist, landmark maps, star charts, S/C systems data, orbital map, and experiments checklist. Stowage is in a fiberglass container 23 inches long, 9.46 inches wide, and 1.75 inches deep. It has a hinged cover to contain the manuals when the container is removed from its stowage compartment in LEB. The container has nylon ribbon tab on each end to aid in pulling it out of the compartment. The compartment has a door with a simple bar latch to restrain the container.

FLIGHT DATA FILE (GFP)

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6.10

CREWMAN IN-FLIGHT TOOL SET AND WORKSHELF (GFP).

The crewman in-flight tool set provides multipurpose tools and attachments for Apollo mission activities. The crewman in-flight tool set (figure 6-19) contains the following:

- Torque wrench
- Adapter handle
- 10" driver
- 5/32" short hex driver
- 7/32" hex driver
- 4" torque set driver
- Emergency wrench
- 2 T-handles
- 2 end wrenches
- 20" tether
- D-ring extension handle

Operationally, the tools are designated by a letter (A, B, C, D, etc.).

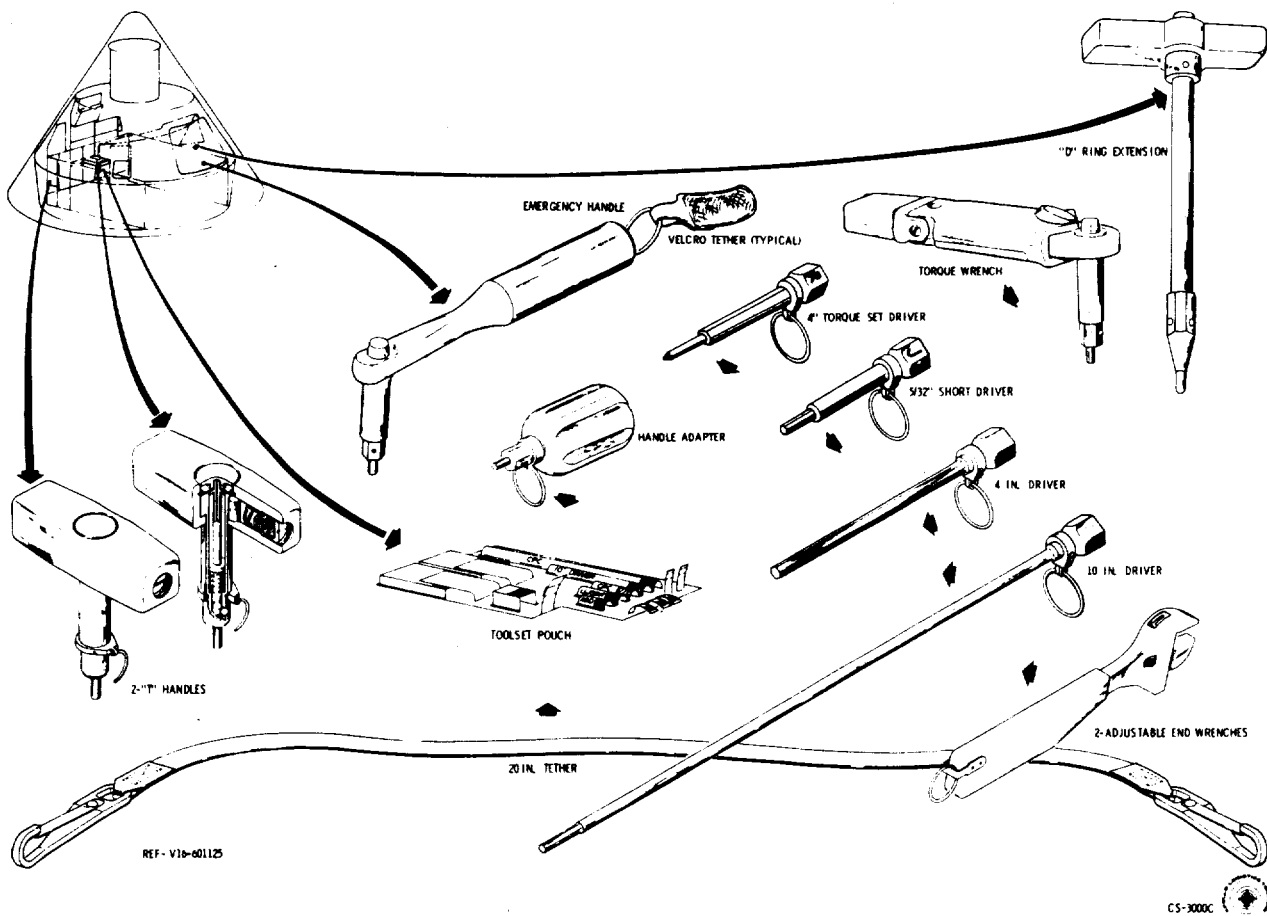


Figure 6-19. Crewman In-Flight Tool Set Configuration, Block I

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6.10.1 TORQUE WRENCH (TOOL A).

The torque wrench has a torque limiting capacity of approximately 35 to 200 inch-pounds in the clockwise direction. It has a ratchet capability in the clockwise and counterclockwise direction. The pawl, which indicates operation, has three positions which are marked CW, LOCK, and CCW. The maximum torque capability in the LOCK position is approximately 400 inch-pounds.

The dual driving lug has a 7/16-inch hex male wrench with a ball-lock and a 5/32-inch hex male wrench. The drive lug fits all drivers. The pushbutton on top of the shaft controls the ball-lock which locks the drivers on. The lug reaches 2-1/4 inches beyond the face of the wrench.

Torque settings of 50, 100, 150, and 200 inch-pounds are calibrated and marked. The setting can be set by rotating the knob at the end of the handle and observing the bar in the slot on the underside of the handle. The following symbols indicate the torque values:

- = 50 inch-pounds
- ⊕ = 100 inch-pounds
- ▴ = 150 inch-pounds
- = 200 inch-pounds.

6.10.2 ADAPTER HANDLE (TOOL E).

The adapter handle is approximately 3.5 inches long and 1.5 inches in diameter. It has a dual driving capability of 7/16- and 5/32-inch hexes and fits all drivers. A ball detent will assist in maintaining contact with the drivers.

6.10.3 10-INCH DRIVER (TOOL H).

All drivers have a 7/16-inch internal hex drive socket. The 10-inch driver is 11.125 inches long with a 10-inch shaft. The shaft end has a 5/32-inch hex drive.

6.10.4 4-INCH DRIVER (TOOL L).

The 4-inch driver is 5.125 inches long with a 4-inch hex shaft of 7/32-inch.

6.10.5 EMERGENCY WRENCH (TOOL B).

The emergency wrench is 6.25 inches long with a 2.5-inch drive shaft. The drive shaft has two hex drives: 7/16- and 5/32-inch. It is capable of applying a torque of 1475 inch-pounds and is a backup for the torque wrench. It has a ball-lock device to lock it in a drive. It is essentially a modified Allen head L-wrench.

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6.10.6 T-HANDLE (TOOL C).

There are two T-handles per tool set. The T-handle is 2.75 inches long with an aluminum body. It has a 3/8-inch diameter ball-lock shaft with a 5/32-inch hex wrench. There is a torque break feature, calibrated by an adjustable screw at 35±5 inch-pounds, and then sealed. The ball-lock device is released by a pushbutton on the top of the handle.

6.10.7 END WRENCH (TOOL F) (2).

The adjustable end wrenches are a modified crescent wrench. It is very lightweight, made of aluminum, with an isotactic foam handle. The jaws openings width is from 1/4 inch to 1 inch.

6.10.8 5/32-INCH SHORT DRIVER (TOOL J).

The 5/32-inch short hex driver is 3.62 inches long with a 5/16-inch round shaft and a 5/32-inch hex drive of 0.7 inch.

6.10.9 4-INCH TORQUE SET DRIVER (TOOL R).

The 4-inch torque set driver has a No. 10 torque set on one end and a 5/16-inch driver on the other end.

6.10.10 IN-FLIGHT TOOL SET TETHER.

The tool set tether is a 20-inch strap with snaps at each end. Each tool has a tether ring or band to which the tether snap can be attached.

6.10.11 D-RING EXTENSION HANDLE (TOOL N).

The D-ring extension handle is a rod with a T-handle approximately 7 inches long. The rod end has a guide point tapering to a 7/16-inch hex about an inch long. Every other hex surface has a ball-lock. The T-handle has a pushbutton that controls the balls.

6.10.12 OPERATIONAL USE.

The in-flight tool set tools have multiple uses. Figure 6-20 is a matrix table for tool usage.

In the CM, items operated or adjusted by tools will have a small square placard nearby designating the tool (A through N and R) and the torque setting of the torque wrench. If the torque wrench is not used, just the designating letter (0.19-inch high) will be indicated.

The tool set is designated to be used either in the shirtsleeve environment or the PGA pressurized status.

6.10.13 STOWAGE. (Figure 6-19)

The tool set tools are stowed at various places. For launch and entry, some are stowed in positions ready for an emergency. During orbit, the tools are stowed in a location that affords easy access.

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CREWMAN IN-FLIGHT TOOL SET AND WORKSHELF (GFP)

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Function (Designator)		Torque Wrench	10" Driver	7/32" Hex Driver	5/32" Hex Sht Drvr	Emergency Wrench	Adapter Handle	"T" Handle (2)	Crank Handle	Adj End Wrench (2)	"D" Ring Ext. Handle	4" Torque Set Driver
A	H	L	J	B	E	C	D	F	N	R		
P = Primary Use B = Backup E = Emergency												
A. Environmental Control System												
1. Open/close ECS valves on water (315) and O <sub>2</sub> panel (314). (LHEB)	B						B	P				
2. Close water-glycol accumulator isolation valve on panel 312. (LHEB)	P	P					B					
3. Unlatch/latch fasteners of ECU panel (313) over LiOH filter. (LHEB)	B	P					P					
4. Open/close water delivery device valve (304). (LHEB)	B							P				
5. Tighten fluid and gas line connections. (LHEB)										P		
6. Unlatch/latch fasteners of cabin atmosphere recirc. screen. (LHEB)	B	P					P					
7. Unlatch/latch fasteners (3) of access panel to coolant control panel (311). (LHEB)	B						P	P				
B. Guidance, Navigation, and Control System												
1. Unlatch/latch fasteners of "LOOSE PARTS STOWAGE" cover for G&N handles. (LHFEB)	B	P					P					
2. R/R G&N handles (2) on G&N panel. (LEB)	P						B					
3. R/R rotational control adapter on G&N panel (105). (LEB)	B	P					P					
4. R/R optics panel (104) cover. (LEB)	P						B					

Figure 6-20. Crewman In-Flight Tool Set Usage Chart (Sheet 1 of 2)

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Function (Designator)	P = Primary Use B = Backup E = Emergency										
	Torque Wrench A	10" Driver H	7/32" Hex Driver L	5/32" Hex Sht Drvr J	Emergency Wrench B	Adapter Handle E	"T" Handle (2) C	Crank Handle D	Adj End Wrench (2) F	"D" Ring Ext. Handle N	4" Torque Set Driver R
5. Adjust scanning telescope shaft and trunnion axis. (LEB)				P		P					
6. Wind/set GMT clock (panel 306). (LHFEB)				P		B					
7. R/R sextant short and long eyepiece from eyepiece.	B	P				P					
8. R/R scanning telescope short and long eyepiece from eyepiece assembly.	B	P				P					
<b>C. Mechanical Systems</b>											
1. Adjust crew couch headrest.	B		P			P					
2. Adjust couch upper armrest.	B		P			P					
3. Stow translational control adapter-center couch legrest.	B		P			P					
4. Open side crew pressure (inner) hatch from C/M.					E						
5. Open side crew heatshield/thermal hatch from C/M (Emer).					B						
6. R/R sea water access tube plug. (LHEB)	P	P				B					
7. Lock/unlock couch footstraps when PGA pressurized.										P	
8. Tighten/loosen mirror U-joints.											P
<b>D. Mission Experiments</b>											
1. Lock/unlock screws (2) of SCIENT EQUIP B drawer.	B	P				P					

Figure 6-20. Crewman In-Flight Tool Set Usage Chart (Sheet 2 of 2)

CREWMAN IN-FLIGHT TOOL SET AND WORKSHELF (GFP)

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6.10.13.1 In-Flight Tool Set Stowage Pouch and Tool Set Drawer.

The tool set pouch is located in the tool set drawer on the LEB. The workshelf is stowed in the drawer on top of the tool set. The following tools are stowed in the pouch.

- 10" Driver
- 4" Driver
- 5/32" hex short driver
- 4" torque set driver
- Adapter handle
- 2 end wrenches
- Tether

The pouch is 21.25 inches long and 7.5 inches wide and is made of green nylon cloth. It has a small pouch with a retention strap for each tool and is marked with the tool name and designation. The tool set pouch is held to the drawer bottom by Velcro strips on the underside. The tether will be attached to a driver tether ring and laid in the drawer. The tool set drawer slides in and out on tracks and is held closed by a latch. In a corner of the drawer, a polyurethane block with a cutout for the torque wrench is located.

6.10.13.2 Miscellaneous Stowage.

The T-handles are stowed in the ECS panels at all times when not in use.

The emergency wrench is placed in the inner hatch latch mechanism for the mission. If it is needed, it can be removed and used.

The D-ring extension handle is stowed near the light fixture on the right girth, shelf-accessible to the pilot.

6.10.14 WORKSHELF ASSEMBLY. (Figure 6-21)

The workshelf assembly provides a table for food preparation and map/manual reading.

The workshelf is of aluminum sheet construction approximately 24 by 10.5 inches. At each end, there is a hinged support frame with slide latches. The shelf has two pivots so that it can be folded lengthwise, making storage easier. When stored, it is 24.5 by 6 by 1 inches.

The working top of the shelf is surfaced with Velcro hook material. Items that will be used in conjunction with the shelf will be equipped with Velcro pile material, facilitating zero-g restraint.

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CREWMAN IN-FLIGHT TOOL SET AND WORKSHELF (GFP)

CREW PERSONAL EQUIPMENT

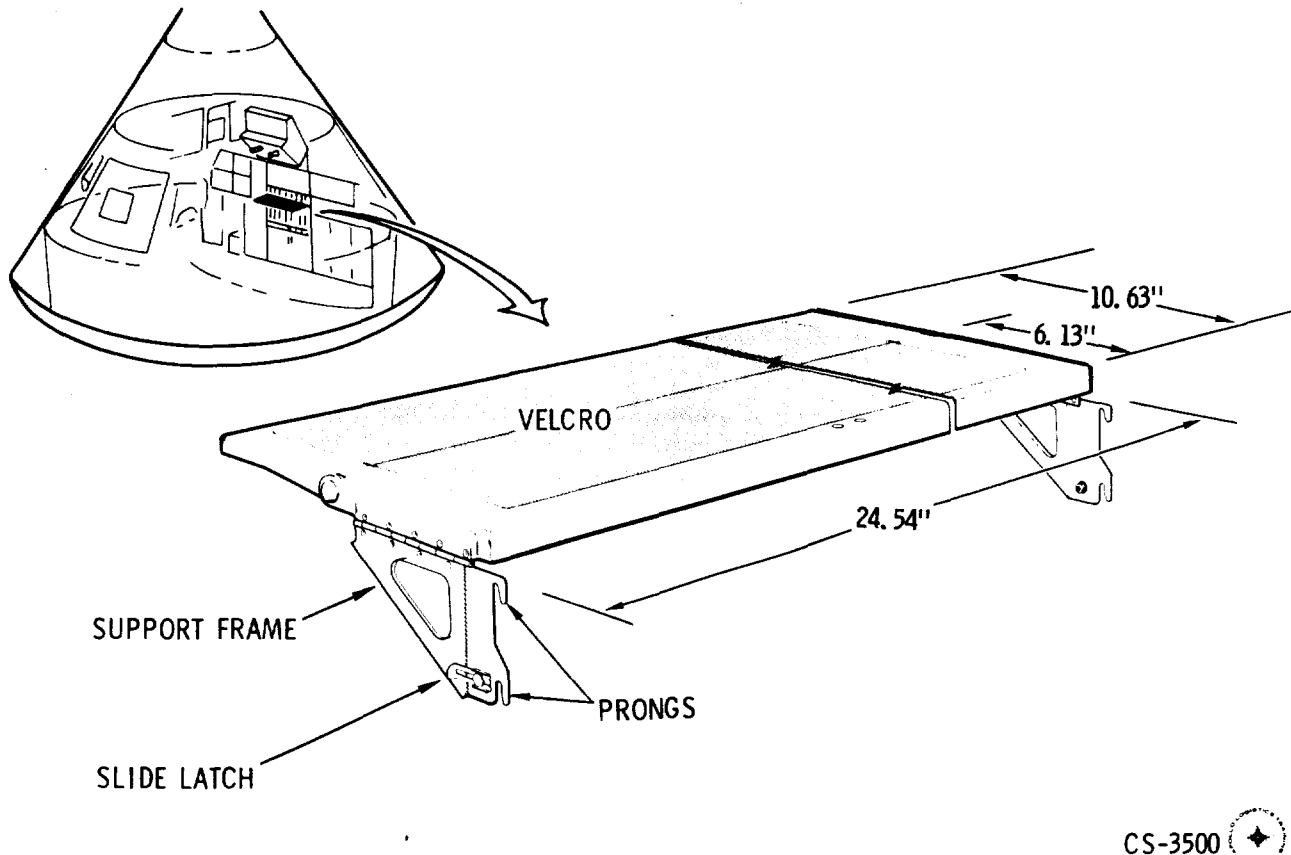


Figure 6-21. Workshelf, Block I

6.10.14.1 Usage.

The workshelf is stored in the lower equipment bay in the tool set drawer next to the flight data file storage. To remove, slide drawer out, lift, and unfold the shelf. Flip the support frames to the extended position and install on the lower bulkhead girth shelf below the G&N equipment by slipping the prongs into the slots. The prongs rest on small pins. Lock the shelf in by actuating the slide latch on each support frame. To remove, reverse the installation process and store.

The food packages and flight data manuals have patches of Velcro pile to interface with the workshelf surface.

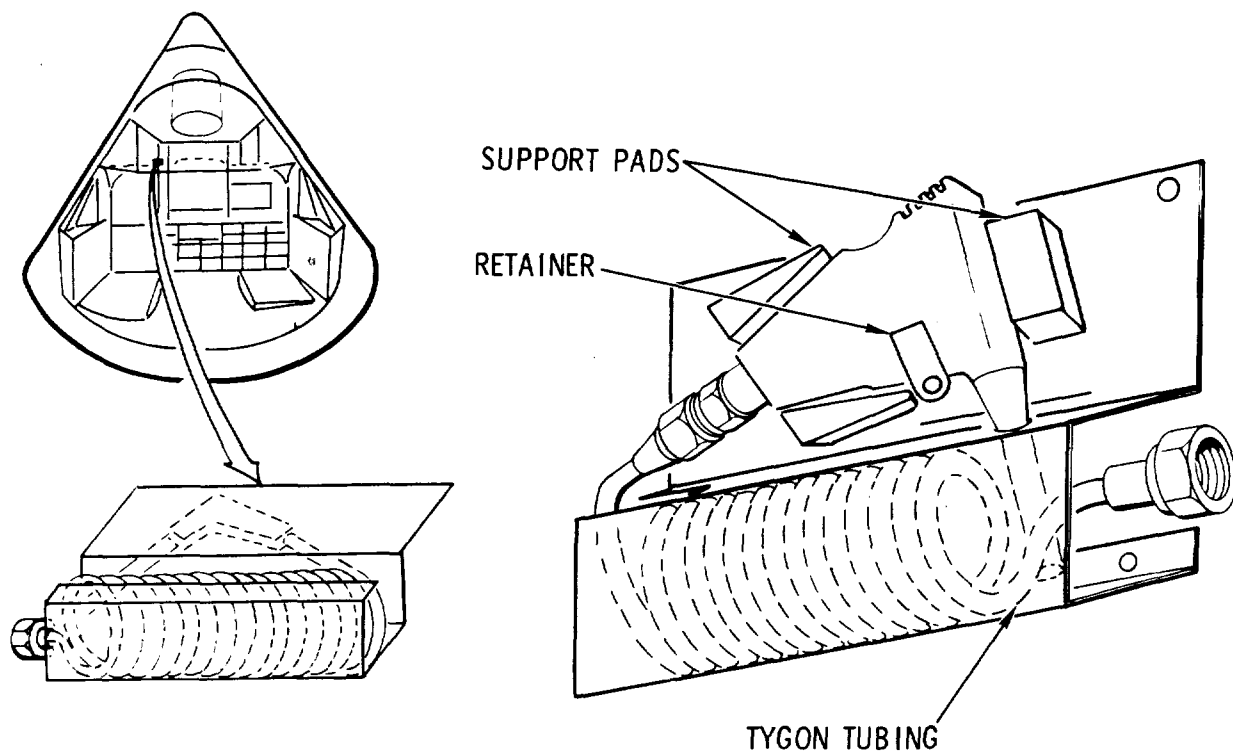
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6.11 DRINKING WATER SUBSYSTEM. (Figure 6-22)

The source of cold water for drinking is the water chiller. It is the same line that is routed to the cold water tap of the potable water tank. The crewman drinking water line is T'd off, routed through a shut-off valve, to the water dispenser located beneath the main display panel structure. It is handy to the left and center couch positions.

The water dispenser assembly consists of an aluminum mounting bracket, a coiled hose, and a water delivery valve in the form of a push-button actuated pistol. The pistol is GFE. It meters one-half ounce portions of water when the pushbutton is pressed. An accumulative counter is also on the side. It has a safety pushbutton to prevent discharge of water when passing the pistol from one crewman to the other. The uncoiled hose will




CS-4101B 

Figure 6-22. Crewman Water Dispenser Assembly

DRINKING WATER SUBSYSTEM

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reach 72 inches. When the pistol is returned to the mount, the hose will re-coil into the housing. The pistol is stored in the mounting bracket and is held in place by a retainer.

During orbit, an alternate position is located on the MDC. The pistol is held in place by Velcro tabs.

6.12 FOOD.

The food furnishes a balanced diet of approximately 2650 calories per day to each crewmember. The astronaut's daily requirement for an earth orbital mission is 2650 calories. His daily intake will be 1.2 pounds of food, 6 pounds of water, and 2 pounds of oxygen. He will give off about 2.2 pounds of CO<sub>2</sub>.

The food is in many forms such as dehydrated, freeze-dry, and bulk. It consists mainly of a highly nutritious and concentrated food. The food is packaged in plastic bags of a special design to allow food to be vacuum packaged. The food bag has a one-way poppet valve through which the potable water supply nozzle is inserted. The bag has another valve through which the food passes. The food bags are packaged in aluminum foil-backed plastic bags to make one meal for each astronaut. Breakfast, lunch, and snacks will be recycled every 4 days during the mission and the dinner every 8 days. The bags have red, white, and blue dots to identify them for the individual crewman.

6.12.1 USE.

The freeze-dry food is reconstituted by adding hot or cold water through a one-way valve on the food bag neck. It is then kneaded by hand for approximately 3 minutes. When the food is reconstituted, the neck is cut or torn off and placed in the mouth. A squeeze on the bag forces food into the mouth. When finished, a germicide tablet, attached to the bag, is slipped through the mouth piece, an ounce of water added, and the bag shook. The germicide will prevent fermentation and gas. The bag is then rolled as small as possible and returned to the food stowage drawer.

6.12.2 STOWAGE.

Food is stowed in three areas: the food stowage compartment in the lower equipment bay (LEB) on the left hand side, the auxiliary food compartment in the C/U-hand equipment bay (RHEB), and the food stowage compartment in the left-hand equipment bay (LHEB). Combined, they offer approximately 6,006 cubic inches of food storage volume.

6.12.2.1 LEB Food Stowage Compartment.

The food stowage compartment is structurally separate from the CM support structure and contains five bins and five drawers. The combined drawer volume is approximately 3725 cubic inches. The compartment is 23 inches high, 20 inches wide, 23 inches deep, and is constructed as a unit.

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DRINKING WATER SUBSYSTEM—FOOD

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The top, bottom, right side, and shelves are 0.25-inch honeycombed aluminum sandwich. The left side is sheet aluminum 0.063-inch thick. The retainer doors are aluminum sheet and hinged at the bottom. The doors are latched at the top with latch bolts that pin into the side support structure.

The food stowage drawers are constructed of 0.020-inch-thick fiberglass; the largest weighs about 26 ounces. The end to be opened has a net closure held in place by Velcro providing easy access when the door is opened.

6.12.2.2     RHEB Auxiliary Food Compartment Drawer.

The auxiliary food compartment drawer is separate from the food stowage compartment and is located on the right-hand equipment bay. The volume is approximately 1000 cubic inches and its dimensions are 29 inches long, 10 inches high, and 10 inches deep.

The auxiliary food compartment drawer is a 3-ply, fiberglass box 0.030 inches thick. The front has a net closure hinged at the bottom and attached at the top by Velcro. It is supported structurally on an aluminum shelf and two sheet aluminum stops in the Z-Z direction. Its rear side fits against the inner structure face sheet. An aluminum door holds the drawer in and gives structural support.

6.12.2.3     LHEB Food Stowage Compartment.

The LHEB food stowage compartment has a volume of 1281 cubic inches. The food stowage drawer is a fiberglass drawer similar in construction to the other food drawers, with a net closure on the front. The drawer rests in the structure and is held in place by a sliding door.

6.13     PERSONAL HYGIENE (GFP). (Figure 6-23)

Personal hygiene items consist of an oral hygiene assembly containing a toothbrush and ingestible gum, wet and dry cleaning cloths, and towels.

6.13.1     CLEANSING OF TEETH - ORAL HYGIENE ASSEMBLY.

An effective method of cleansing teeth is Trident brand chewing gum. It is chewed and then swallowed. One stick is used after each of four meals per day. A stick is approximately 1 by 7/8 inch. To maintain healthy gums, a toothbrush for massaging by brushing is used. The brush also has a rubber prong on the handle for dislodging food particles.

These items are packaged in a one-man module to be used for a 14-day period. The module contains one toothbrush and 28 packs of gum. In each pack, there are two sticks giving a total of 56 sticks per astronaut. The module is stored in the first days food storage drawer to be used for the entire mission.

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FOOD—PERSONAL HYGIENE (GFP)

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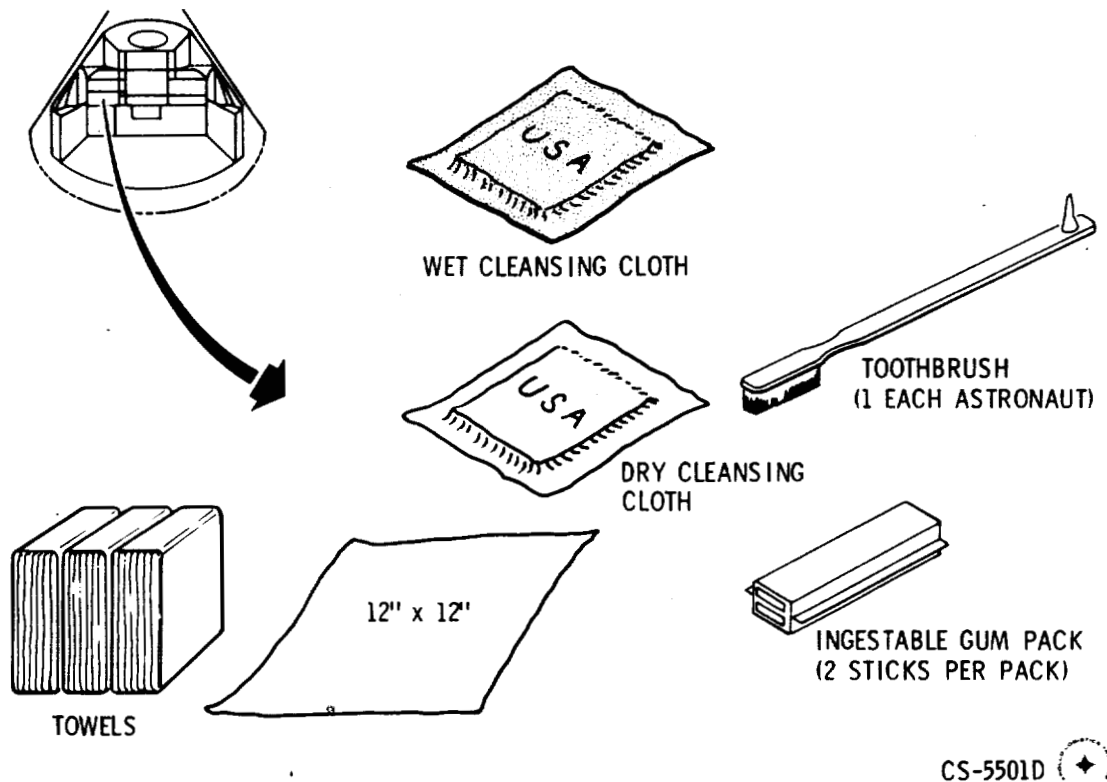


Figure 6-23. Personal Hygiene Items

6.13.2 WET CLEANSING CLOTH.

Wet cleansing cloths will be used for post-meal and post-defecation hygiene. The cloths are 4 by 4 inches folded into a 2-inch square and sealed in plastic. They are saturated with a germicide and water. The cloths for post-meal cleansing are stored, along with the dry cleansing cloth, in the food packages for easy accessibility. The post-defecation cleansing cloths (62 or more) are located in a sanitation supply stowage box.

6.13.3 DRY CLEANING CLOTH.

The dry cleaning cloths will be alternated with the wet cleansing cloths for post-meal cleanup. They are the same size and texture; however, they do not contain water and a germicide. They are also packaged with the food. There are 168 wet and dry cleansing cloths to be placed in the food packages.

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PERSONAL HYGIENE (GFP)



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6.13.4 TOWELS.

The towels will be used for utility purposes. There are 21, each 12 by 12 inches, and packaged in 3 plastic bags. One bag is stowed on the left couch, and two bags are stowed in the RHEB.

6.13.5 TISSUE DISPENSERS.

The cleansing tissues will also be used for defecation cleanup and utility use. There are nine tissue dispensers, seven are located on the back of the center couch, and two in other areas. They are mounted with Velcro.

6.14 MEDICAL SUPPLIES (GFP).

The medical equipment is used for the following:

- Monitor current physiological condition of the crewmen.
- Furnish medical supplies for treatment of crewman in-flight medical emergencies.

The medical equipment is subdivided into two functional types: monitoring equipment and emergency medical equipment. The monitoring equipment includes the clinical physiological monitoring instrument set, personal biomedical sensors instrument assembly, biomedical preamplifier instrument assembly, and the personal radiation dosimeters. There is also a bioinstrumentation accessories kit for spares. The emergency medical equipment is the emergency medical kit.

6.14.1 MONITORING EQUIPMENT.

6.14.1.1 Clinical Physiological Monitoring Instrument Set.

There is a requirement for periodic measurements of body temperature, blood pressure, heart beat rate, and respiratory rate to be logged by the crewman. This set of instruments will accomplish the measurements. The instruments include the following:

- Individual thermometers for body temperature measurements
- Aneroid sphygmomanometer for measuring blood pressure
- Stethoscope for heart beat measurement.

The physiological monitoring set is stored in the forward medical compartment of the LEB.

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6.14.1.2     Personal Biomedical Sensors Instrument Assembly.

Constant monitoring of the heart beat and respiration is required. The sensors assembly automatically and continually senses these functions when the main display panel switch is positioned to the crewman to be monitored. The personal biomedical sensors instrument assembly consists of the following:

- Electrodes (silver silver chloride), 4 or more
- Accessories, such as paste and application tape.

The sensors will be used to gain the following:

- 2 electrocardiographs (ECG)
- Respiration rate.

The sensor assemblies are attached to the body of the astronaut at areas of sparse muscles (to reduce artifact level) by use of paste and tape, and remain throughout the mission.

6.14.1.3     Biomedical Preamplifier Instrument Assembly.

Because of their weak magnitude, the sensor signals have to be amplified before being telemetered. This function is performed by the preamplifiers (or signal conditioners). The preamplifiers are about the size of a cigarette pack and weigh about 100 grams. They operate on a source voltage of 16.8 volts, therefore one dc-dc converter. There are three preamplifiers which are to be used for the following measurements:

- ECG No. 1
- ECG No. 2 or phonocardiograph (uses same preamplifier)
- Respiration rate

The preamplifiers fit into pockets in the constant wear garment, circumferentially around the stomach diaphragm. Wire leads connect to the sensors, which act as electrodes. The sensors act as an electrode for one or more preamplifiers. The difference of resistance between two electrodes is measured. Muscle activity (breathing) changes the skin resistance and this change is measured and sent to the telemetry equipment. One electrode or sensor can be wired to more than one lead for a preamplifier. Each preamplifier will have a lead (to an umbilical) terminating with a connector. The connectors will plug into a larger common umbilical.

6.14.1.4     Bioinstrumentation Accessories Kit.

A kit of spares and possible use for additional scientific experiments will be located in the right-hand equipment bay on the kick ring adjacent to the LEB. The kit will have 35 sensors, 50 micropore discs, 8 wet wipe towels, and 1 tube of electrolyte paste.

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MEDICAL SUPPLIES (GFP)

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6.14.1.5 Personal Radiation Dosimeters.

The crew will wear five passive dosimeters in the form of film packs in the CWG. One crewman will also wear an ionization chamber of the active type in his CWG. Personal dosimeter information will not be telemetered.

6.14.2 MEDICAL KIT (GFP).

The medical supplies are contained in oral drugs, injectable drugs, dressings, topical agents, and an inhaler. The content of the medical kit is as follows:

Oral Drugs

Drug	Use	No. of Tabs
Bismuth subcarbonate	Fever, pain reducer	24
Darvon compound 65	Fever, pain reducer	12
Globaline	Suppresses infection of gastro-intestinal system	50
Tigan, Bonodoxin, or Marezine	Anti-nauseant (6-man day treatment)	24
Dexedrine	Stimulant	12
Acromycin (250 mg)		24
Elective medication		9

Injectable Drugs

Drug	Use	No. of Units
Morphine Sulphate Demerol	Pain killer	3
Tigan, Bonodoxin, or Marezine	Anti-nauseant	3

Drug is contained in an automatic medical injector

MEDICAL SUPPLIES (GFP)

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Dressings		
Item		Qty Reqd
Elastic bandage or compress (3" x 60")		2
Band-aids (1" x 3")		12
Topical Agents and Inhaler		
Item	Use	Qty Reqd
General purpose ointment, antibiotic	Skin irritations	2 (1/2 oz. tubes)
Benzedrex inhaler	Anti-nasal congestant	1

6.14.2.1 Packaging.

The medical kit is in a single package, accessible at all times during the mission. The package is approximately 4 by 5-1/2 by 4 inches and weighs 2.1 pounds.

6.14.2.2 Storage. (Figure 6-24)

The medical kit will be stowed on the back of the left couch lower leg support.

6.14.2.3 Medical Kit Additional Usage.

In the event the astronauts have to evacuate the command module during the recovery phase, the medical kit will be detached from the couch and carried by an astronaut.

6.15 SURVIVAL KIT (GFP).

There are two survival kits with three packages in each. One package contains three rafts; the other package contains water and miscellaneous survival equipment. They are readily accessible from the right-hand forward equipment bay by the right-hand seat occupant. The kits and containers weigh approximately 70 pounds. In addition to the survival kit, a sea water pump is provided. The pump is used after splashdown if the crew requires water and the onboard supply is exhausted.

6.15.1 STOWAGE.

The kits and the sea water pump are stowed in the right-hand forward equipment bay. They are inserted into the structural framework from the bottom and held in place by a quick-release bar retainer.

SURVIVAL KIT (GFP)

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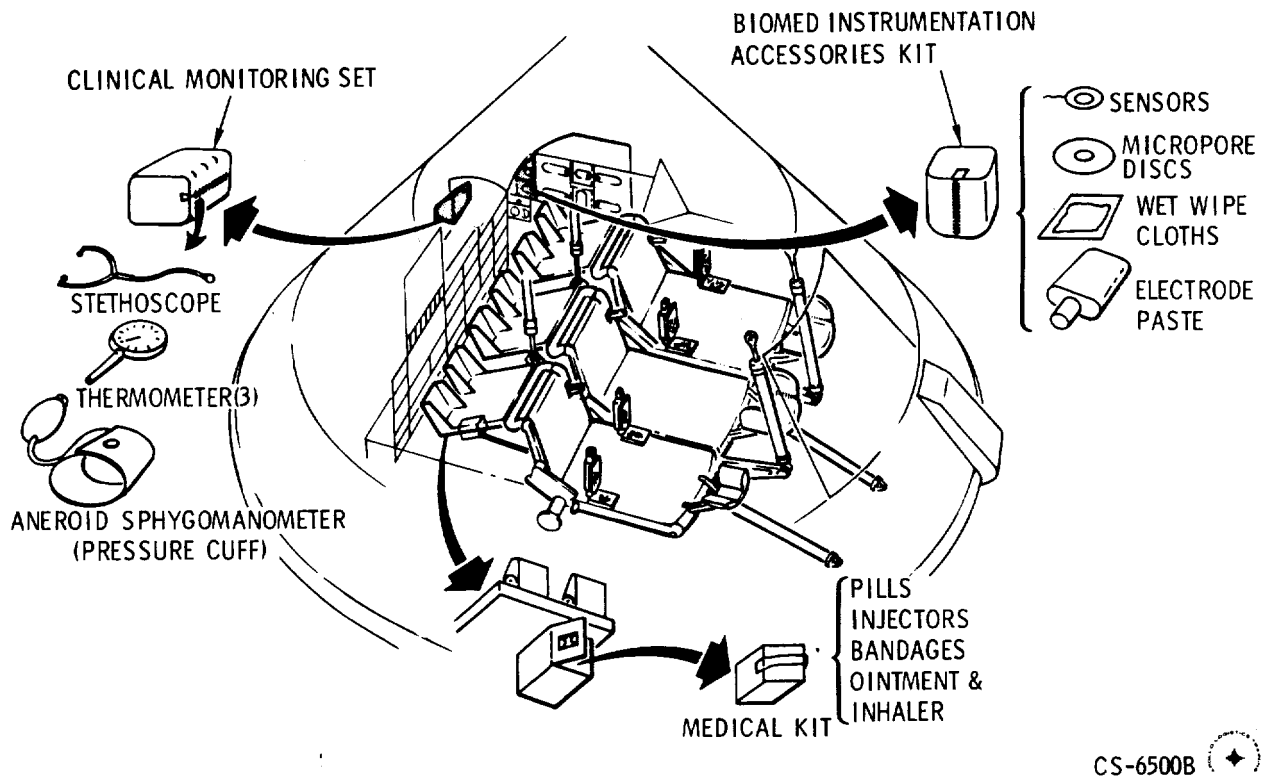


Figure 6-24. Medical Supplies and Equipment C/M Locations

The individual kits are contained in fiberglass boxes called a survival provisions container assembly (hereafter called a container). Thickness varies from 0.040 inch to 0.070 inch, and varies in ply from 4 to 7; a ply being 0.101 inch. One end is a cover and is attached by a breakaway hinge and locked close by a hinge and pin assembly. The cover has Dacron webbing straps that act as a handle. The weight and volumes are as follows:

Container	Weight	Volume
No. 1	5 pounds	0.90 cubic feet
No. 2	4.25 pounds	0.85 cubic feet

MEDICAL SUPPLIES (GFP)—SURVIVAL KIT (GFP)

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6.15.2 SURVIVAL KIT CONTAINER OPERATION.

After impact, and if the CM is damaged or sinking, it has been determined by the crew commander to evacuate, the pilot will release the survival containers by pulling a ring on the bar retainer. He will hand a container to each of the other astronauts. Two astronauts must retrieve the flight data mission logs. The side hatch is removed and the astronauts enter the water. In the water, container top is removed by (1) pulling hinge pin completely out and discarding and (2) rotating top against breakaway hinge until it falls off. Reach inside, pull out contents, activate the one-man raft and climb aboard.

6.15.3 CONTENTS OF THE SURVIVAL KITS. (Figure 6-25)

Container No. 1 contains two cloth pouches. One pouch contains three aluminum containers, each with 5 inches of water. The second pouch contains the following:

- Survival radio with battery
- Survival radio battery
- 2 combination survival lights
- 3 survival glasses
- 2 survival knives
- 2 desalting kits with 16 tablets

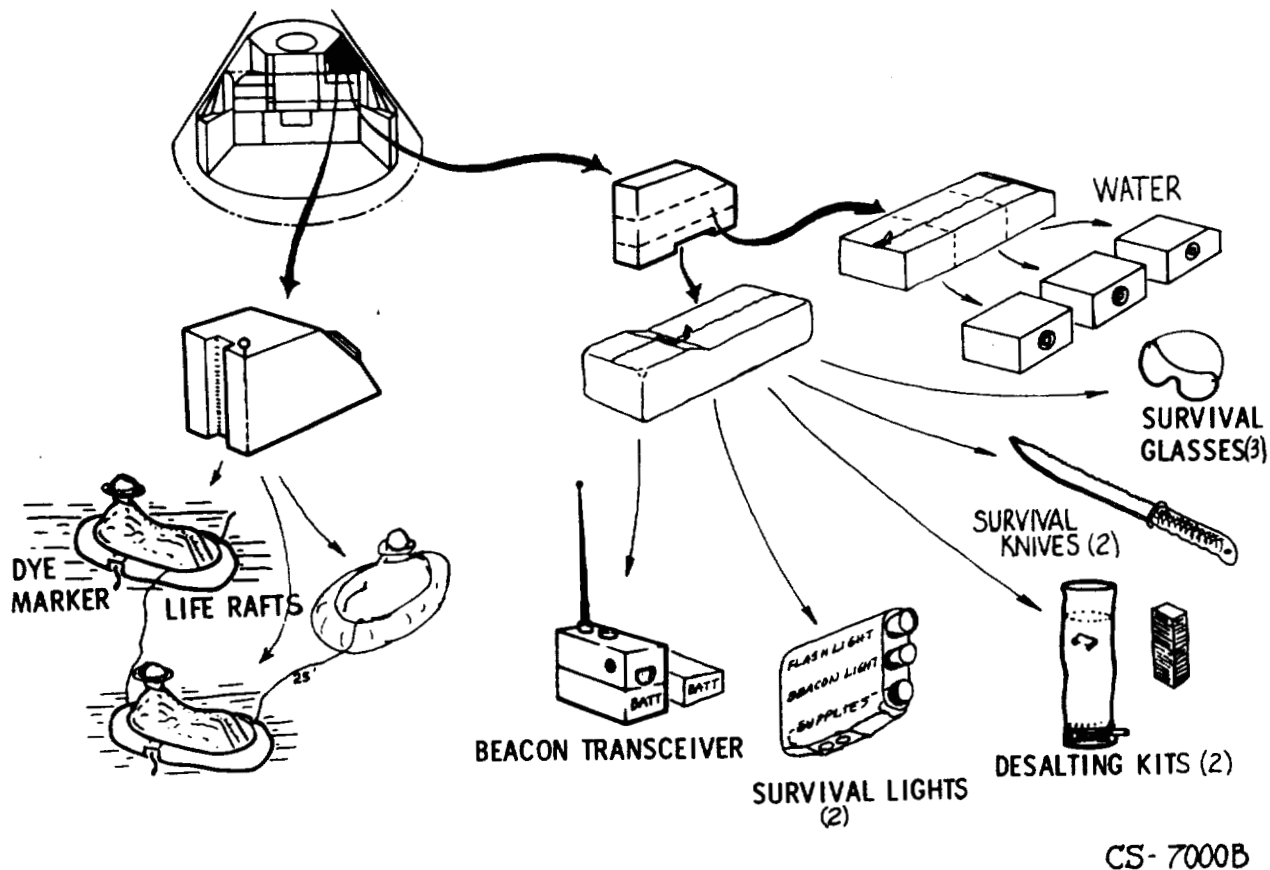


Figure 6-25. Apollo Survival Kit and Components, Block I

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Container No. 2 contains one pouch with three one-man liferafts tethered together with 25-foot tethers. The pouches open by use of zippers and have lacings on the bottom to adjust the fit.

6.15.4 DESCRIPTION AND USE OF SURVIVAL KIT COMPONENTS.

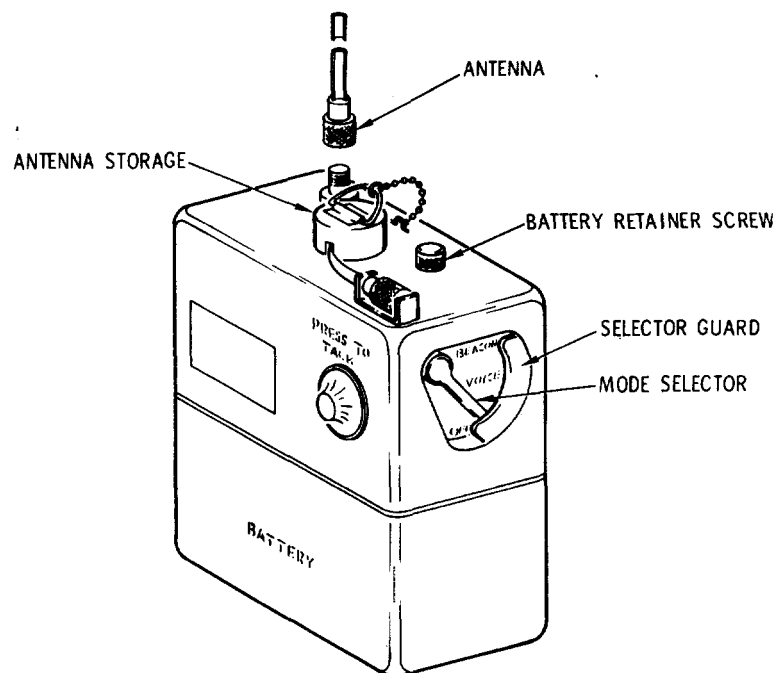
6.15.4.1 Liferafts.

The liferafts are of lightweight nylon or mylar and inflated with CO<sub>2</sub>. Each has a sea anchor, sponge pad, sun bonnet, tether, and sea dye marker.

6.15.4.2 Beacon/Transceiver.

The UHF beacon/transceiver is a hand-held, battery-powered radio, fixed-tuned to a VHF frequency of 243 mc and manufactured by Sperry Phoenix Company. The radio consists of a receiver-transmitter assembly, a battery pack assembly, and a quarter-wave antenna (figure 6-26). The receiver-transmitter assembly and battery pack assembly mate to form a watertight unit measuring 8 by 4-1/2 by 3 inches. The antenna is an 11-1/2-inch-long tapered, flexible steel tape, terminating in a coaxial RF connector, and is normally stored in a retaining spool and clip on top of the radio unit.

The radio is capable of line-of-sight operation in either of two modes (beacon or voice) through use of either its own antenna or a suitable



CS-7025

Figure 6-26. Survival Beacon/Transceiver Radio

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connected remote antenna. The transmitter output is protected against damage while operating due to accidental shorting of the antenna or submergence of the unit in salt water. In the beacon mode, the transmitter operates unattended, for periods up to 24 hours, to transmit an interrupted 1000 cps tone, amplitude-modulated 25 percent on the 243 mc RF carrier. In the voice mode, the radio provides two-way AM voice communication through use of an integral speaker-microphone and push-to-talk switch. An extra battery is included in the pouch.

The following is a summation of the operating characteristics:

Characteristic	Voice Mode	Beacon Mode
Average power output	1.2 watts into a 50-ohm resistive load	2 watts into a 50-ohm resistive load
Frequency	243 mc carrier. 300 to 3000 cps voice signal	243-mc carrier, 1000-cps signal
Modulation	90-percent maximum	25 percent
Duty cycle	Continuous when PUSH-TO-TALK switch is pressed	2 seconds on 3 seconds off
Receiver sensitivity	10 db signal plus noise-to-noise ratio with 7.5 microvolts signal on antenna	

6.15.4.3 Survival Lights (2).

The survival light is a three units in one device as it contains three compartments. The whole device is waterproof. The controls for the light are on the bottom.

The first unit is a flashlight. The second unit is a strobe light for night signaling. The third unit is a waterproof compartment containing a fish hook and line, a "sparky" kit (striker and pith balls), needle and thread, and whistle. The top of the unit is a compass and on one side is a signal mirror that folds flat to the case.

6.15.4.4 Survival Glasses (3).

For protection of the eyes against the sun and glare, three survival glasses are included. They are a polarized plastic sheet with Sierra Coat III, a gold coating that reflects heat and radio waves.

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6.15.4.5 Survival Knives (2).

The survival knives are protected with a cloth sheath. The knives are very thin with razor edges. The back edge is a saw.

6.15.4.6 Water Cans (3).

One pouch contains three aluminum water cans, one for each crewman. The cans have a drinking valve and hold 5 pounds of water.

6.15.4.7 Desalting Kits (2) Plus Tablets (16).

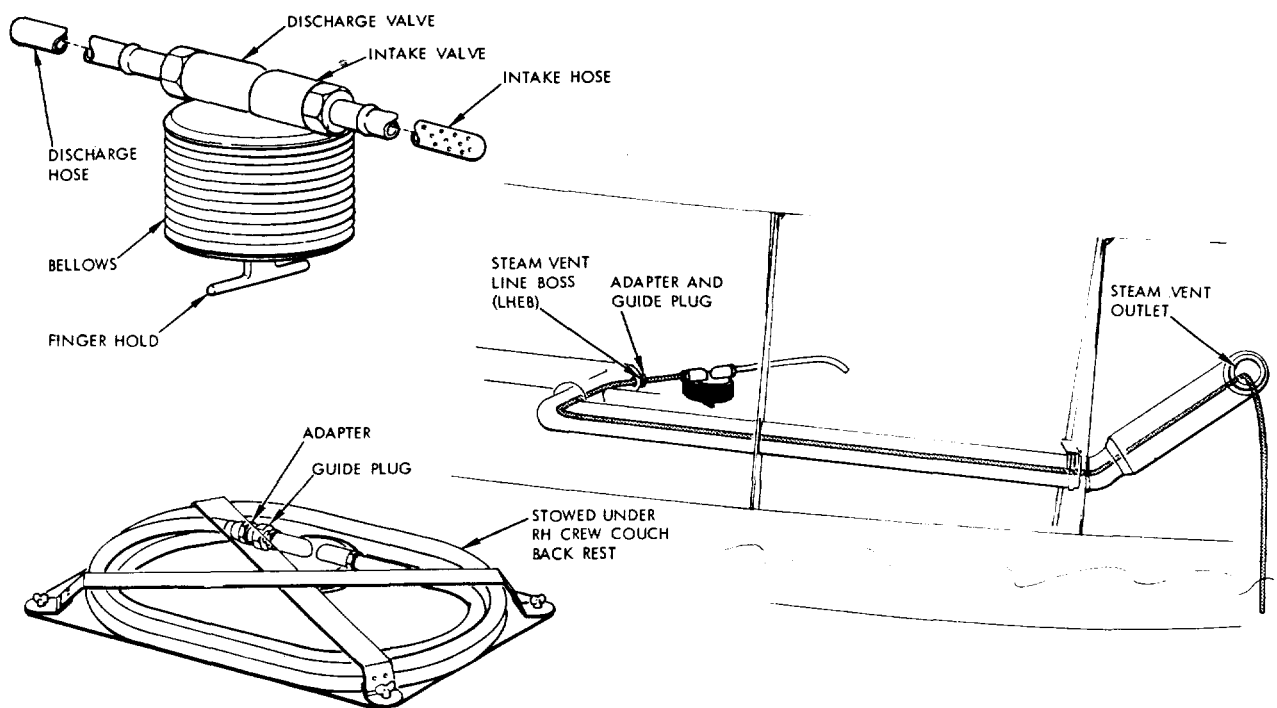
The desalting kits are plastic bags with a filter at the bottom. Approximately one pint of water is put in the bag and one tablet added. The water is desalted after approximately one hour.

6.15.4.8 Emergency Medical Survival Kit.

In the event the medical kit cannot be retrieved before egress, an emergency medical survival kit is in the survival kit. It contains 6 band-aids, 6 injectors, 30 tablets, and one tube of all purpose ointment.

6.15.5 SEA WATER PUMP (CFE). (Figure 6-27)

The pump assembly contains an intake check valve, a discharge check valve, and a 3-inch-diameter bellows, which is operated by means of a fingerhold and extends 1-1/8 inches from a 2/5-inch compressed thickness.



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Figure 6-27. Sea Water Pump

SURVIVAL KIT (GFP)

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A 10-foot-long plastic hose, fitted with a guide plug and an adapter, is attached to the intake valve; a 1-foot-long hose is attached to the discharge valve. To use the pump, the plug is removed from the steam vent hose located just forward of the aft bulkhead in the LHEB; the adapter on the intake hose is threaded into the boss; and the perforated end of the intake hose is fed through the guide plug into the steam vent, along the vent about 5 feet to the vent outlet, and through the outlet into the sea. The guide plug is then tightened into the adapter to form a seal around the hose, and the bellows is extended and compressed to pump water from the short discharge hose into the desalting kit bag. The pump is packaged in a semiflexible plastic container and stowed on the backside of the RH couch position legrest.

6.16

STOWAGE.

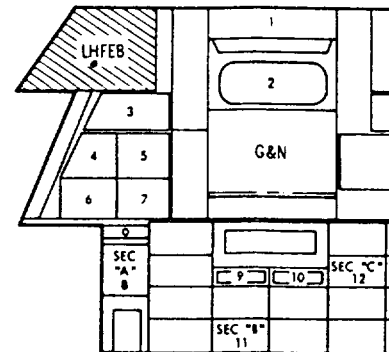
The numerous activities of the crew make housekeeping very important. All loose equipment must be stowed during launch and boost. Prior to entry, loose equipment must be stowed for entry and landing. Figure 6-28 defines S/C 012 stowage locations for equipment.

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SURVIVAL KIT (GFP)—STOWAGE

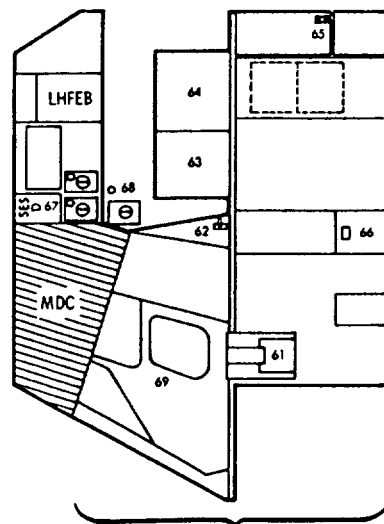
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STOW AREA	LEB STOWAGE ITEMS	STOW AREA	LEB STOWAGE ITEMS
1 A B C D	"G&N EYEPiece" COMPARTMENT SHORT TELE EYEPiece SHORT SEXTANT EYEPiece LONG TELE EYEPiece OPTICS FILTER	9 A B C D E F	SR PILOT FLT "DATA FILE" DWR NAVIGATOR CHECK LIST LANDMARK MAPS S/C SYSTEM DATA EXPERIMENTS CHECKLIST STAR CHART ORBITAL MAP
2	G&N OPTICS PAN COVER	10 A B C D E F G H I J	"TOOL-TABLE" DRAWER WORKSHELF A - TORQUE WRENCH E - ADAPTER HANDLE F - 2 END-WRENCHES H - 10" DRIVER J - 4" X 5/32" SHORT DRIVER L - 4" CPC" (7/32") DRIVER R - 4" TORQUE SET DRIVER TETHER TOOLSET POUCH
3	"FOOD A" CONTAINER	11 A B C D	"SCIENT EXP B" DRAWER M009 GOGGLES 3 M009 MOUTHPIECES 7 16MM FILM PACKS 8 70MM FILM PACKS
4	"FOOD B" CONTAINER	12 A	"SCIENT EXP C" DWR MED DATA ACQ SYS (MDAS)
5	"FOOD C" CONTAINER	13 A B C	"CLIN MON INSTR SET" COMP CLIN MON INSTR SET URINE RECEPTACLE & TRANSFER VALVE ASSY 3 UCD CLAMPS
6	"FOOD D" CONTAINER	14 A	"TOWELS" COMPARTMENT 14 TOWELS (2 PKGS)
7	"FOOD E" CONTAINER		
8 A B C D E F G H I J K L M N	"SCIENT EXP A" COMPARTMENT 16MM CAMERA W/FILM PACK 16MM CAMERA POWER CABLE 18MM LENS (16MM CAMERA) 25MM LENS (16MM CAMERA) 100MM LENS (16MM CAMERA) 16MM CAMERA MIRROR ASSY 3-16MM FILM PACKS 70MM MASS CAMERA W/RING SIGHT & FILM PACK 250MM LENS (70MM CAMERA) 2-70MM FILM PACKS EXPOSURE DIAL SPOTMETER LOWER VASCULAR SUPPORTS BINOCULARS		

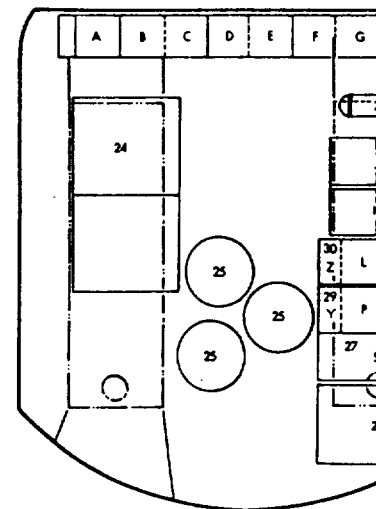


LOWER EQUIPMENT BAY (LEB)

STOW AREA	LHEB STOWAGE ITEMS
61	COMDR DATA FILE BAG
62	T-HANDLE
63 A	"FOOD" COMPARTMENT FOOD STOW SUP CONT
64 A B C	"CWG & SANDAL" COMP 3 CWG'S 3 FLT OVERALLS 3 PR SANDALS
65	T-HANDLE
66	REMOVABLE ECS ATTEN PAN
STOW AREA	LHFEB STOWAGE ITEMS
67 A B C	"SCIENTIFIC EXP D" COMP SCIENT EQUIP STOW BOX "D" OCTOPUS CABLE DEWPOINT CONT UNIT W/ELEC CABLE, SENSOR & CABLE
68 A B C D	3-CREWMAN UMPL ASSY'S 3 O <sub>2</sub> HOSE ASSY W/NOZZLES 3 COMRA CABLES 3 PGA ELEC ADAPTERS 3 ELECT. COMRA "T" ADAPTERS

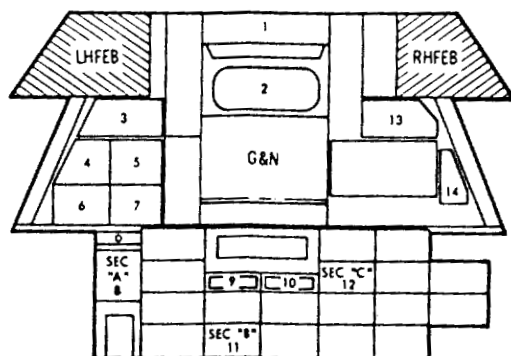
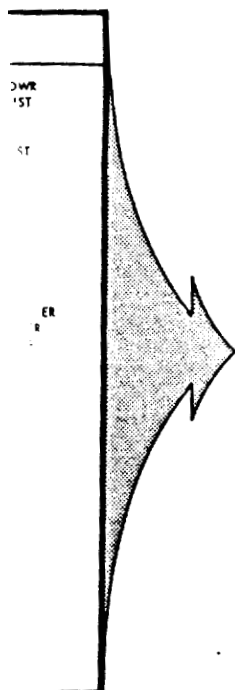


LEFT HAND EQUIPMENT BAY (LHEB)



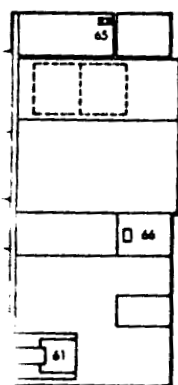
AFT BULKHEAD (AB)



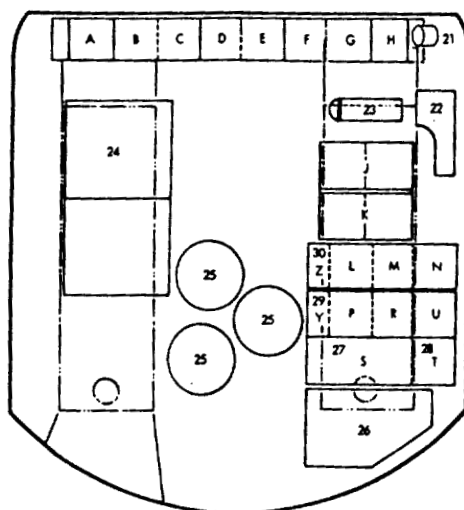


LOWER EQUIPMENT BAY (LEB)

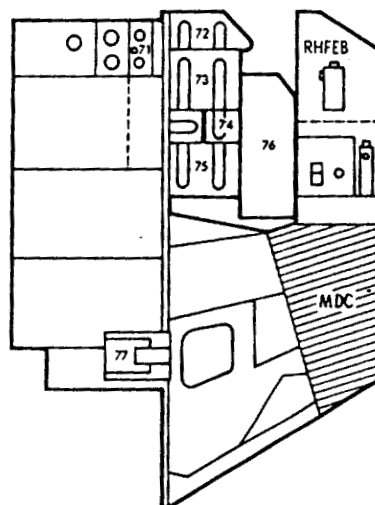
STOW AREA	AFT BULKHEAD STOWAGE ITEMS	STOW AREA	AFT BULKHEAD STOWAGE ITEMS
A-H J,K L,M,N P,R,U	16 L10H CARTRIDGES 4 L10H CARTRIDGES 3 L10H CARTRIDGES 3 L10H CARTRIDGES	25 A B	3 PGA HEL STOW BAGS 3 COMM SOFT HAT 3 LIGHTWEIGHT HE
21	M003 INFLIGHT EXERCIZER	26 A	R/H PGA STOW BAG R/H SLEEP RESTRAIN
22 A	TV OPTICS CONTAINER TV ZOOM LENS	27 A B	COMPARTMENT "S" SPARE URINE LINE F CREW OP ALIGN SIC POWER CORD 1 COAS BULB & SPAR 2 PPK'S
23 A	FECAL CANISTER URINE FILTER ASSY W/POUCH	28 A B	COMPARTMENT "T" M009 CAMERA BRKT PPK
24 A B C	L/H PGA STOW BAG 3 CREWMAN WASTE BAGS L/H SLEEP RESTRAINT FECAL CANISTER PAD	29	COMPARTMENT "Y"
		30 A	COMPARTMENT "Z" 9 PENLIGHTS



LEFT HAND EQUIPMENT BAY (LHEB)



AFT BULKHEAD (AB)

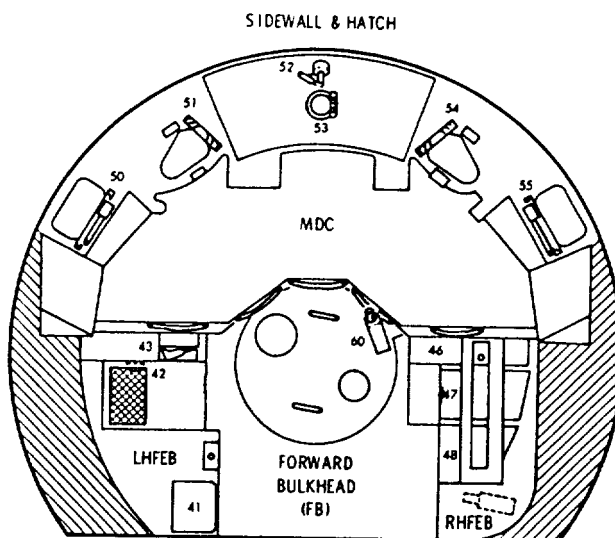


RIGHT HAND EQUIPMENT BAY (RHEB)

STOW AREA	RHEB STOWAGE ITEMS
71 A B	"VACUUM CLEANER" COMPART VACUUM CLEANER ASSY W 5 VAC CLEAN REF BAG ASS FE OUTER BAG DEBRIS BAG GERMICIDE POUCH TIF BAND
72 A	"MEDICAL ACCESSORIES KIT" CI BIO-MED ACCESSORIES KIT 35 ELECTRODES 50 MICROPORE DISCS 1 ELECTRODE PASTE 8 WET-PIPE TOWELS
73 A B C	"SCIENT EXF E/TOWELS" COMP 1000 NEPHLOMETER 10 SAN SUP ASSY'S 7 TOWELS (1 PKG) 5 VAC CLEAN REF BAG ASSY
74 A B	"ELECT ADAPTERS" COMP 3 CWG ELECT ADAPTERS 2 SLEEP ELEC ADAPTERS
75 A	"SANITATION SUPPLIES" COMP SAN SUP BOXES A, B & C 52 SAN SUP ASSY'S
76 A	"FOOD COMPARTMENT AUX FOOD CONTAINER
77 A B	PILOT FLT DATA FILE BAG ENGR CHECK-LIST MISSION LOG & DATA

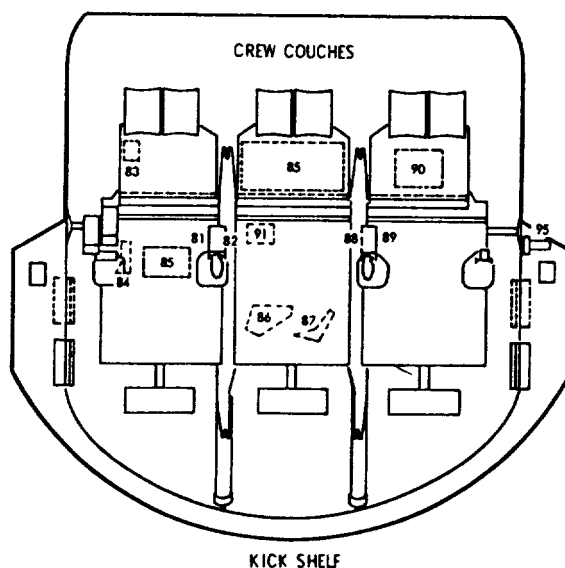


STOW AREA	AFT BULKHEAD STOWAGE ITEMS
25 A B	3 PGA HEL STOW BAGS 3 COMM SOFT HATS 3 LIGHTWEIGHT HEADSETS
26 A	R/H PGA STOW BAG R/H SLEEP RESTRAINT
27 A B C D	COMPARTMENT "S" SPARE URINE LINE FILTER CREW OP ALIGN SIGHT & POWER CORD 1 COAS BULB & SPARE 2 PPK'S
28 A B	COMPARTMENT "T" MO09 CAMERA BRKT PPK
29	COMPARTMENT "Y"
30 A	COMPARTMENT "Z" 9 PENLIGHTS



STOW AREA	LHFEB STOWAGE ITEMS
41 A B C D	"LOOSE PARTS" COMPARTMENT G&N SHORT HANDHOLD G&N LONG HANDHOLD LEB ROT CONTROL MOUNT LONG SEXTANT EYEPIECE
42	FAN CLOSURE
43	WATER DISPENSER (PISTOL)
STOW AREA	RHFEB STOWAGE AREAS
46 A B	SURVIVAL KIT CONT "A" SURV KIT RUCKSACK (1) SURV KIT RUCKSACK (2)
47 A B	SURVIVAL KIT CONT "B" SURVIVAL KIT RUCKSACK (3) SEA HOSE & PUMP
48	SURVIVAL KIT CONT "C"

STOW AREA	RHEB STOWAGE ITEMS
71 A B	"VACUUM CLEANER" COMPARTMENT VACUUM CLEANER ASSY W/HOSE 5 VAC CLEAN REF BAG ASSY'S FE OUTER BAG DEBRIS BAG GERMICIDE POUCH TIF BAND
72 A	"MEDICAL ACCESSORIES KIT" COMP BIO-MED ACCESSORIES KIT 35 ELECTRODES 50 MICROPORE DISCS 1 ELECTRODE PASTE 8 WET-PIPE TOWELS
73 A B C	"SCIENT EXP E/TOWELS" COMP T003 NEPHELOMETER 10 SAN SUP ASSY'S 7 TOWELS (1 PKG) 5 VAC CLEAN REF BAG ASSY'S
74 A B	"ELECT ADAPTERS" COMP 3 CWG ELECT ADAPTERS 2 SLEEP ELEC ADAPTERS
75 A	"SANITATION SUPPLIES" COMP SAN SUP BOXES A, B & C 32 SAN SUP ASSY'S
76 A	"FOOD COMPARTMENT AUX FOOD CONTAINER
77 A B	PILOT FLT DATA FILE BAG ENGR CHECK-LIST MISSION LOG & DATA



STOW AREA	CREW COUCH STOWAGE ITEMS
81	STA 1 LWR ARMREST, R/H
82	STA 1 ROTATION CONTROL
83	EMERGENCY MEDICAL KIT
84	TRANS CONTROL ADAPTER
85	7 TISSUE DISPENSERS
86	TV CAMERA MOUNT
87	16 MM CAM. MOUNT
88	STA 3 LOWER ARM REST L/H
89	STA 3 ROTATION CONTROL
90 A B C	"SCIENT EXP G" COMP 16 MM CAMERA 70 MM CAMERA (5UP WIDE ANGLE) 5 MM LENS (16 MM CAM)
91	EVAPORATOR TEMP SENSOR
STOW AREA	KICK-SHELF STOWAGE ITEMS
95	"D" RING EXTEN HANDLE

FIGURE 1-15-1

OLDOUT FRAME 3

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CREW PERSONAL EQUIPMENT

LHFEB STOWAGE ITEMS	STOW AREA	SIDEWALL & HATCH STOWAGE ITEMS
"LOOSE PARTS" COMPARTMENT G&N SHORT HANDHOLD G&N LONG HANDHOLD LEB ROT CONTROL MOUNT LONG SEXTANT EYEPIECE	50	LEFT SIDE VIEW WIND SHADE
FAN CLOSURE	51	LEFT REAR WIND SHADE
WATER DISPENSER (PISTOL)	52	TOOL B- EMER WRENCH
	53	HATCH SHADE
	54	RIGHT REAR WIND SHADE
	55	RT SIDE VIEW WIND SHADE
RHFEB STOWAGE AREAS	STOW AREA	TUNNEL STOWAGE ITEMS
SURVIVAL KIT CONT "A" SURV KIT RUCKSACK (1) SURV KIT RUCKSACK (2)	60	TV CAMERA W/ WIDE ANGLE LENS
SURVIVAL KIT CONT "B" SURVIVAL KIT RUCKSACK (3) SEA HOSE & PUMP		
SURVIVAL KIT CONT "C"		

APOLLO EQUIPMENT STOWAGE (LAUNCH)

(S/C 012)

DATE: 1 AUG 1966  
REV: 1 OCT 1966

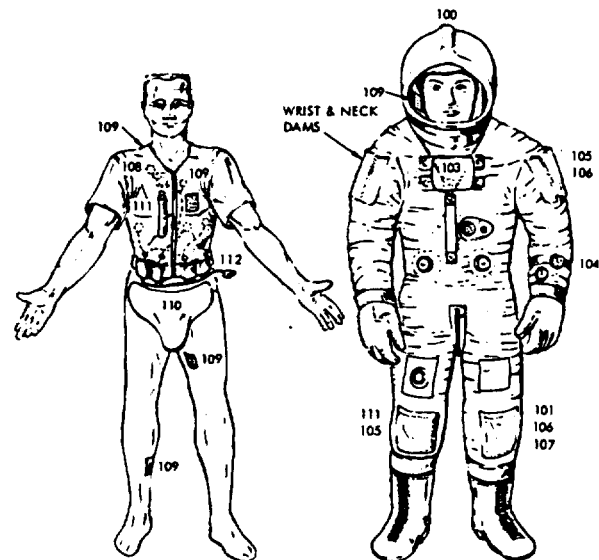
"MARKED" COMPARTMENT

A-R, U - AFT BKHD LION STORAGE CONTAINERS (BOXES)  
SEC A-E, G - SCIENTIFIC EXPERIMENT COMPARTMENTS  
S, T, Y, Z - MISC SCIENT EXP EQUIP & CREW EQUIP  
FOOD A-E - LEB FOOD COMPARTMENTS

CHART  
NUMBERING  
SYSTEM

1 - 20 LEB  
21 - 40 AFT BULKHEAD  
41 - 60 LHFEB, RHFEB, SIDEWALL & HATCH,  
TUNNEL  
61 - 70 LHEB  
71 - 80 RHEB  
81 - 99 CREW COUCH & KICKSHELF  
100 - CREW APPAREL

CREW COUCH STOWAGE ITEMS	ITEM	STOW AREA	CREW APPAREL (EACH CREWMAN)
STA 1 LWR ARMREST, R/H	100	24/28	PGA
STA 1 ROTATION CONTROL	101	CREW	PENLIGHT
EMERGENCY MEDICAL KIT	102	CREW	SUN GLASSES W/CONT
TRANS CONTROL ADAPTER	103	24	LIFE VEST
7 TISSUE DISPENSERS	104	CREW	CHRONOGRAPH W/WATCH BAND
TV CAMERA MOUNT	105	CREW	2 MARKING PENS
16 MM CAM. MOUNT	106	CREW	2 MECHANICAL PENCILS
STA 3 LOWER ARM REST L/H	107	CREW	SURGICAL SCISSORS
STA 3 ROTATION CONTROL	108	64	CWG
"SCIENT EXP G" COMP 16 MM CAMERA 70 MM CAMERA (SLIP WIDE ANGLE) 5 MM LENS (16 MM CAM)	109	CREW	5 PASSIVE DOSIMETERS
EVAPORATOR TEMP SENSOR	110	WASTE	URINE COLLECTION DEVICE
	111	CREW	POCKET DOSIMETER (1 FOR 3)
	112	CREW	BIO-INSTRUMENT HARNESS
KICK-SHELF STOWAGE ITEMS			
"D" RING EXTN HANDLE			



CS-9700A



Figure 6-28. Crew Equipment Stowage

STOWAGE

Mission \_\_\_\_\_ Basic Date 12 Nov 1966 Change Date \_\_\_\_\_ Page 6-51/6-52

**OLDOUT FRAME**

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SYSTEM SCHEMATICS

SECTION 7

SYSTEM SCHEMATICS

**NOTE** This section will contain a brief description of each system, utilizing charts, flow diagrams, and schematics. Information for this section will be provided at a later date by MSC.

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SYSTEM SCHEMATICS



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Sections 8 through 11 will be submitted at a later date.



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APPENDIX A

APPENDIX A  
SYMBOLS AND DEFINITIONS

AB	Aft bulkhead	BCN	Beacon
A/C	Audio center	BECO	Booster engine cutoff
ACCEL	Accelerometer	BIOMED	Biomedical
ACCUM	Accumulator	BLWR	Blower
ACE	Acceptance checkout equipment	BMAG	Body-mounted attitude gyro
ACK	Acknowledge	BPC	Boost protective cover
ADA	Angular differentiating accelerometer	bps	Bits per second
ADAP	Adapter	Btu	British thermal unit
ADJ	Adjust	BUR	Backup rate
AESB	Aft equipment storage bay	BURR	Backup rate roll
AF	Audio frequency	BURP	Backup rate pitch
AF	Atmospheric flight	BURY	Backup rate yaw
AGAA	Attitude gyro accelerometer assembly	CA (OH) <sub>2</sub>	Calcium hydroxide
AGC	Apollo guidance computer	CAUT/WARN	Caution and warning
AGC	Automatic gain control	cb	Circuit breaker
AGCU	Attitude gyro coupling unit	cc	Cubic centimeter
AM	Amplitude modulation	CCW	Counterclockwise
AMPL	Amplifier	CDU	Coupling display unit
AMS	Apollo mission simulator	CF	Coasting flight
ANAL	Analyzer	CFE	Contractor-furnished equipment
ANLG	Analog	cfm	Cubic feet per minute
ANT	Antenna	CG	Center of gravity
ASD	Apollo standard detonator	CHGR	Charger
ASD	Astro sextant door	CIR & SEP	H <sub>2</sub> circulation, water separation centrifuge, and glycol circulation
ASI	Apollo standard initiator	C/M	Command module
AS/GPI	Attitude set/gimbal position indicator	CMD	Command
ATT	Attenuator	C/M RCS	Command module reaction control system
ATT	Attitude	COAS	Crewman optical alignment sight
AUTO	Automatic	COMP	Compressor
AUX	Auxiliary	COMP	Computing
AVC	Automatic volume control	COMPR	Compressor
BAT	Battery	COND	Condenser
BCD	Binary coded decimal	COND	Conditioner
		CONT	Control
		CO <sub>2</sub>	Carbon dioxide
		CPC	Coldplate clamp

SYMBOLS AND DEFINITIONS

